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# ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

FC

REPORT NO. 282
17 January 1957

## A SURVEY OF HEARING LOSSES AMONG ARMOR PERSONNEL*

*Subtask under Psychophysiological Studies, AMRL Project No. 6-95-20-001, Subtask, Noise and Vibration Problems.

RESEARCH AND DEVELOPMENT DIVISION
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

Army Medical Research Lab, Ft. Knox, Ky.

A SURVEY OF HEARING LOSSES AMONG ARMOR PERSONNEL -J. L. Fletcher and L. N. Solomon

Report No. 282, 29 Aug 56 - 40 pp & ii - Appn. 3
24 illus - 5 talbes - Project 6-95-20-001 -
Unclassified Report

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Subtask AMRL S-3
MEDEA


## ABSTRACT

## A SURVEY OF HEARING LOSSES AMONG ARMOR PERSONNEL

### OBJECT

To relate the hearing losses of armor personnel to their age, noise exposure, use of ear protection, previous aural medical history, type of ear protection used (internal or external), and branch of service and type of hearing loss.

### RESULTS

Generally, hearing losses increased with age. This was particularly true of high frequency losses. Hearing loss differences between negligibly and severely exposed subjects were statistically significant. Personnel with a "positive" aural medical history (defined in this study as anyone who has had earaches, ear drainage, mechanical ear injury, or ear or mastoid surgery) had larger hearing losses than did those with a "negative" medical history. Subjects who had experienced tinnitus in a quiet place before being exposed to loud noise and persons whose tinnitus persisted for longer than an hour after exposure to loud noises were shown to have poorer hearing than subjects who did not report these phenomena. Tankers, armor artillerymen, and armor infantrymen were not found to differ in hearing losses. Group audiometry results were found in essential agreement with results from individual audiometry.

### CONCLUSIONS

Results of this study indicate that the effect of high levels of noise exposure upon personnel differs as a function of the age of the exposed person at the time of exposure. This effect appears to be greater than that commonly observed as a function of aging alone (called presbycousis, the normal loss in hearing acuity attributable to aging). Older persons possibly incur greater hearing losses to a given noise exposure than do younger persons.

Two conclusions can be made regarding the use of protection for the ear against noise. The first is that too few persons use adequate

ear protection. The second is that adequate ear protectors appear to be relatively inaccessible to those who do desire to use them.

The findings of this study indicate that personnel with a positive aural medical history will more likely have less acute hearing than will personnel with a negative aural medical history, therefore such personnel were not included in the normative data.

## RECOMMENDATIONS

Results of this study indicate that a hearing conservation program should be initiated and actively pursued for armed forces personnel. Several department of defense agencies (for example, the Preventive Medicine Division of the Office of the Surgeon General, and Working Group 21 of the Armed Forces - National Research Council Committee on Hearing and Bio-Acoustics (CHABA) have recently been concerned with the formulation of hearing conservation programs. Therefore, responsible authorities have good programs already developed from which to choose.

Further research is required to determine whether tinnitus prior to loud noise exposure and persistent tinnitus following loud noise exposure are indicative of susceptibility to noise induced hearing loss or of the amount of hearing loss already incurred.

Submitted 29 August 1956 by:
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## A SURVEY OF HEARING LOSSES AMONG ARMOR PERSONNEL

### I. INTRODUCTION

Technological changes in the Army have resulted in the increasing use of heavy machinery and in the development and use of more powerful weapons on the company level. This has resulted in an increase in the noise levels to which personnel operating these vehicles and weapons are exposed. A recent study (3) of ambient operating noise levels in armored vehicles shows that crew members are exposed to noise levels ranging as high as 115 to 125 decibels (db), depending upon the type of vehicle, its running speed, and the type of terrain on which the vehicle is operated. It is logical to expect that one result of an increase in noise levels would be an increase in the amount of noise-induced hearing loss in personnel.

Information from the Veteran's Administration* indicates that, at present, approximately 50,000 veterans are receiving compensation for service-incurred hearing loss (not including disease of the ear). Assuming the minimum of 10% disability for those drawing compensation pay (at $16.67 per month), service connected hearing losses among separated personnel are now costing a minimum of $833,500 per month for disability pay alone.

In view of the cost to the government for hearing losses which are relatable to service in the armed forces, and of the possibility for successful preventive measures against the occurrence of such hearing losses, it seemed advisable to make a survey of hearing losses among armor personnel and then to relate these losses to the age, previous noise exposure, medical history, use of ear protection, branch of service (i.e., whether the subject is in Armor, Infantry, Artillery, etc.), and type of hearing loss (i.e., whether the hearing loss is a perceptive, conductive, or combined perceptive-conductive loss) as a function of previous noise exposure.

There are certain obvious advantages to testing the hearing of subjects in groups as opposed to testing them individually but, if the results of group audiometry diverge markedly from those of individual audiometry, its use would then be considerably restricted. Therefore, a

*Personal communication from Dr. A. B. C. Knudsen, Director, Physical Medicine and Rehabilitation Service.

comparison was made of certain aspects of the testing of persons one at a time (individual audiometry) and of testing persons in groups (group audiometry).

## II. EXPERIMENTAL

### A. Individual Audiometry

Two Maico model H-1 audiometers were used in making the individual audiometric measurements. The audiometers were calibrated just prior to the beginning of this study and the earphone output of the four earphones did not differ by more than one decibel (db). Frequencies tested were 500, 1000, 2000, 4000, and 8000 cycles per second (cps). Hearing losses from -10 to +100 db could be measured with the Maico audiometers for frequencies of 500, 1000, 2000, and 4000 cps while losses from -10 to +80 db could be determined at 8000 cps.

### B. Group Audiometry

Group audiometry measures were obtained by means of the Navy Electronics Laboratory (NEL) Recorded Warble Tone Hearing Test, fourth revision* (9). For a complete description of the NEL test and method of testing, see Webster's article (9) on the development and use of the NEL warble tone test.

Eighteen subjects were tested simultaneously for the frequencies 500, 1000, 2000, 4000, and 7000 cps. Table 1 gives the range of hearing losses that could be determined for the frequencies tested by the NEL test.

TABLE 1

THE FREQUENCY AND TESTABLE RANGE OF MEASURABLE HEARING LOSSES OF THE NEL TEST

| Frequency of Test Tone (in cps) | Range of Measurable Hearing Loss |
|---|---|
| 500 | -1 to +47 db |
| 1000 | -3 to +45 db |
| 2000 | -4 to +44 db |
| 4000 | -4 to +44 db |
| 7000 | -6 to +42 db |

*The authors wish to express their appreciation to the Navy Dept., the Human Factors Division of the Navy Electronics Lab, San Diego, Calif., and specifically to Dr. J. C. Webster of the Psychophysical branch of NEL, for their cooperation and help in implementing the present research.

C. Hearing Data Questionnaire

All subjects were given a Hearing Data Questionnaire (Figure 1) prior to taking the audiometry test. One of the experimenters presented and explained the items on the sheet to the subjects in order to be certain that they were understood by the subjects. Two other experimenters assisted by providing individual counsel to personnel having

Age________
Total Active Svs ________ Mos.

NAME: ________________ SN: __________ UNIT________

CURRENT NOISE EXPOSURE:
JOB: ________________ LENGTH OF TIME: __________

PROTECTION?
1. ALWAYS 2. FREQ. 3. SELDOM 4. NEVER

TYPE OF PROTECTION:
1. DRY COTTON
2. WAXED COTTON
3. EAR PLUGS
4. EAR MUFFS
5. HELMET
6. OTHER?

PREVIOUS NOISE EXPOSURE:

A. MILITARY

JOBS TIME ON JOB
1.
2.
3.
4.
5.

COMBAT EXPOSURE

HEAVY ARMS YES NO HOW LONG?
LIGHT ARMS YES NO HOW LONG?
BASIC TRNG YES NO TYPE

EVALUATION OF NOISE EXPOSURE:

B. CIVILIAN

JOBS TIME ON JOB
1.
2.
3.
4.
5.

EVALUATION OF NOISE EXPOSURE:

MED. HISTORY
1. AURAL PAIN________ R - L
2. DRAINAGE________ R - L
3. EAR INJURY MECH.________ R - L
4. SURGERY (EAR OR MASTOID)________ R - L
5. TINNITUS PRIOR TO FIRST EXP. ________ R - L
6. TINNITUS FOLLOWING FIRST EXP. ________ R - L

REMARKS:

Fig. 1 Hearing data sheet

difficulty filling out the sheet. The data sheets were checked for accuracy and completeness while the subjects were tested. In any case where it appeared that a subject could be in error, he was questioned individually after his testing was completed. Extreme care was taken to insure maximum validity for items on the hearing data questionnaire because they furnished one of the essential bases for all the analyses. If, for example, a subject had failed to indicate that he held a high noise level job or jobs, his noise exposure might be rated as "negligible" while his audiogram showed rather severe hearing losses.

An explanation of the exact requirements of the subjects for each item of the hearing data questionnaire may be found in Appendix 1.

D. Determination of Job Noise Environments and Noise Exposure Scores

A General Radio Sound Level Meter, Model 759, was used to determine military job noise levels. This meter does not give peak-readings. Therefore, all levels reported from impulse-type sounds (such as gunfire) are lower than they would be if measured by a peak-reading sound-level meter. All readings were made on the flat scale. On the firing ranges, the db level quoted as the exposure level was determined by the average of a series of readings taken at the gunner's ear, at the coach's position, and at the ready line. The artillery noise level readings were made at the crew's positions and the ammo handler's position in the M-7 self-propelled (SP) 105 howitzer. Readings were made inside and outside the M-47 tank and at the ammo handler's position. A series of sound level readings was made during the day at both ends and in the middle of a tracked vehicle maintenance shop.

Table 2 below, presents the ambient noise levels found for the firing ranges, the 105 SP howitzer, the M-47 tank while firing, and the tracked vehicle maintenance shop.

TABLE 2

AVERAGE AMBIENT NOISE LEVELS FOR THE FIRING RANGES 105 SP HOWITZER, AND TRACKED VEHICLE MAINTENANCE SHOP

| Noise Environment | Average Ambient Noise Level |
|---|---|
| M-1, Carbine, and Light Mach. Gun Range | 100-110 db |
| M-7 SP 105 Howitzer* | 123 db |
| M-47 Tank, Firing HE | 134 db |
| Tracked Vehicle Maintenance Shop | 104 db |

*Firing charge 3, a moderate charge.

A recent study (3) of ambient noise levels in armored vehicles (T-41, M-42, M-44, T-59, M-75, T-97, and T-98) reveals that crew members in these vehicles are working in an ambient noise environment of from 115 to 125 db.

A table was made for both military and civilian jobs which listed jobs under 5 categories of loudness (see Table 3-A). This table gives the 5 categories of loudness, their respective noise levels, and the jobs in each category. This order was patterned after that presented by Chapanis, Garner, and Morgan (2, pg. 194). As it was physically impossible to conduct sound level measurements of the civilian jobs our test personnel had held, reasonable estimates based upon available information were made in assigning the civilian jobs listed to noise level categories.

TABLE 3-A

NOISE EXPOSURE RATINGS

| Category | Civilian | Military |
|---|---|---|
| I<br>(70-79 db average to noisy auto) | auto mechanic, power plant, farmer, carpenter | first sgt, supply, cooks, records NCO's, all personnel SP's, all I & E, sgt majors, mail clerks, arty commo chief, wireman, fire direction computor, arty survey spec, operations sgt, admin NCO, armorer arti. (Inf), motor pool |
| II<br>(80-89 db noisy auto to city bus) | pin setter, auto racer, body shop, linotype operator, feed mill, truck driver (gas), lumber yard, rigger (oil field), cotton mill, printing press, paper mill, high voltage test lab, welder, sheet metal shop, merchant marine | arty mechanic, wheel (gas) veh. driver, rifleman, radio operator, dispatcher |
| III<br>(90-99 db city bus to subway train) | coal miner, truck driver (diesel), heavy equipment (outdoors), machinist, construction worker, steam equipment, diesel engines, railroad worker, aircraft factory, merchant marine engine room, glazer and polisher | maint. (wheel veh.), wheel (diesel) veh. driver, ammo sgt, RR squad, mortar sqd ammo handler, rocket launcher, construction |
| IV<br>(100-109 db subway train to twin-engine plane | industrial equipment (indoors) shipyard, pneumatic drill, planer and saw mill, scrap baler | track school, maint. personnel (armd., arty), light arms combat experience, mortar sqd (gunner and asst.) |
| V<br>(110 db and over twin-engine plane to loud thunder painful sound) | foundry, steel mill, boiler factory, joyloader (coal mine), and sand blaster | plt sgt armd, plt sgt arty, field first (armd, arty), tanker, chief section, chief cannoneer, arty; motor sgt (armored), weapons instru heavy arms combat exposure, ammo handler (armd) |

A sample of 101 armor personnel with different jobs were interviewed to get an average of the time that these personnel spent in and around the primary noise sources (the armored vehicles, firing ranges, and tracked vehicle maintenance shops mentioned above). It was found that the median per cent of time that tank crew members spent in their vehicle with the motor running was 50%, the median time on range about 25%, and the median time in the maintenance shop about 10%. This type of analysis was made for as many high-noise level jobs as were found in the sample studied and was continued until it became apparent that job coverage was adequate, i.e., until new jobs ceased to turn up. In addition to verbal reports from personnel holding the various high-noise level jobs, training officers and relevant training directives were consulted in an effort to be as accurate as possible with regard to apportioning time spent around noise sources.

Table 3-A was constructed dividing military and civilian jobs into five categories of intensity of noise (70-79, 80-89, 90-99, 100-109, and 110 db and over). This division of categories of noise exposure was patterned after that of Chapanis, Garner, and Morgan (2, pg. 194). This table was one of two tables used by the experimenters to rate the noise exposure of the subjects.

Table 3-B of time-on-the-job was prepared in order to assign numerical values of exposure which included both the level and the length of time of exposure.* The noise exposure score was obtained by multiplying the exposure category number by the number assigned to the length of exposure. A distribution of possible noise exposure scores was laid out and cut-off points were selected to determine the classes of noise exposure which were labeled negligible, moderate, or severe. The cut-off points were selected to conform to current beliefs in the field of hearing. For example, Rosenblith, et al (4) indicate that continuous exposure to 80 db would not produce hearing loss. Therefore, 80 db (category II in our table) must always result in a negligible hearing loss rating regardless of the length of exposure. Therefore, 6 was set as a cut-off point for the negligible rating. The remainder of the cut-off points were determined in a similar manner. Both the military and the civilian noise exposure ratings were derived in the same manner, i.e., by ascertaining the jobs held, the noise level of the jobs, then

*It was believed that a severe exposure might be reached sooner in category 5, the highest noise level, than in the lower categories of noise exposure. For that reason, a special time of exposure breakdown was made for category 5.

TABLE 3-B

NOISE EXPOSURE DETERMINATION TABLE

| Exposure Category | Time of Exposure |
|---|---|
| 0 (less than 70 db) | 0 = equal to or less than 1-1/2 months consecutive exposure |
| 1 (70-79 db) | 1 = more than 1-1/2 months, up to 3 months |
| 2 (80-89 db) | 2 = more than 3 months, up to 18 months |
| 3 (90-99 db) | 3 = more than 18 months |
| 4 (100-109 db) | |
| 5 (110 db or over) | 2 = up to 3 months consecutive exposure<br>3 = more than 3 months |

| Noise Exposure Score* | Rating of Noise Exposure Score |
|---|---|
| 0<br>1<br>2<br>3<br>4<br>5<br>6 | Negligible |
| 8<br>9<br>10 | Moderate |
| 12<br>15 | Severe |

*The noise exposure score is the product of the exposure category multiplied by the time of exposure index.

multiplying the noise category number by the length of exposure index. Once the civilian and military exposure ratings were determined for a given subject, they were compared and the subject was given the higher of the two ratings as a final rating; that is, if the civilian noise exposure was rated "negligible" and the military exposure "severe", the individual's overall noise exposure would be listed as severe.

## F. Testing Environment

All testing was done in a sound treated room with an ambient noise level averaging 54 db. Figure 2 presents an octave band analysis of the ambient noise in the testing room. The range of these measurements, in both overall level and in octave band, is plotted in Figure 2. The bar at the extreme left in Figure 2 represents the overall values of noise, measured on the "flat" position of the sound level meter. The overall values varied between 52 and 56 db. The next bar to the right, plotted at a frequency of 425 cps, represents the extreme ranges of noise in the octave 300 to 600 cps. The remaining bars are for noises in the higher octaves.

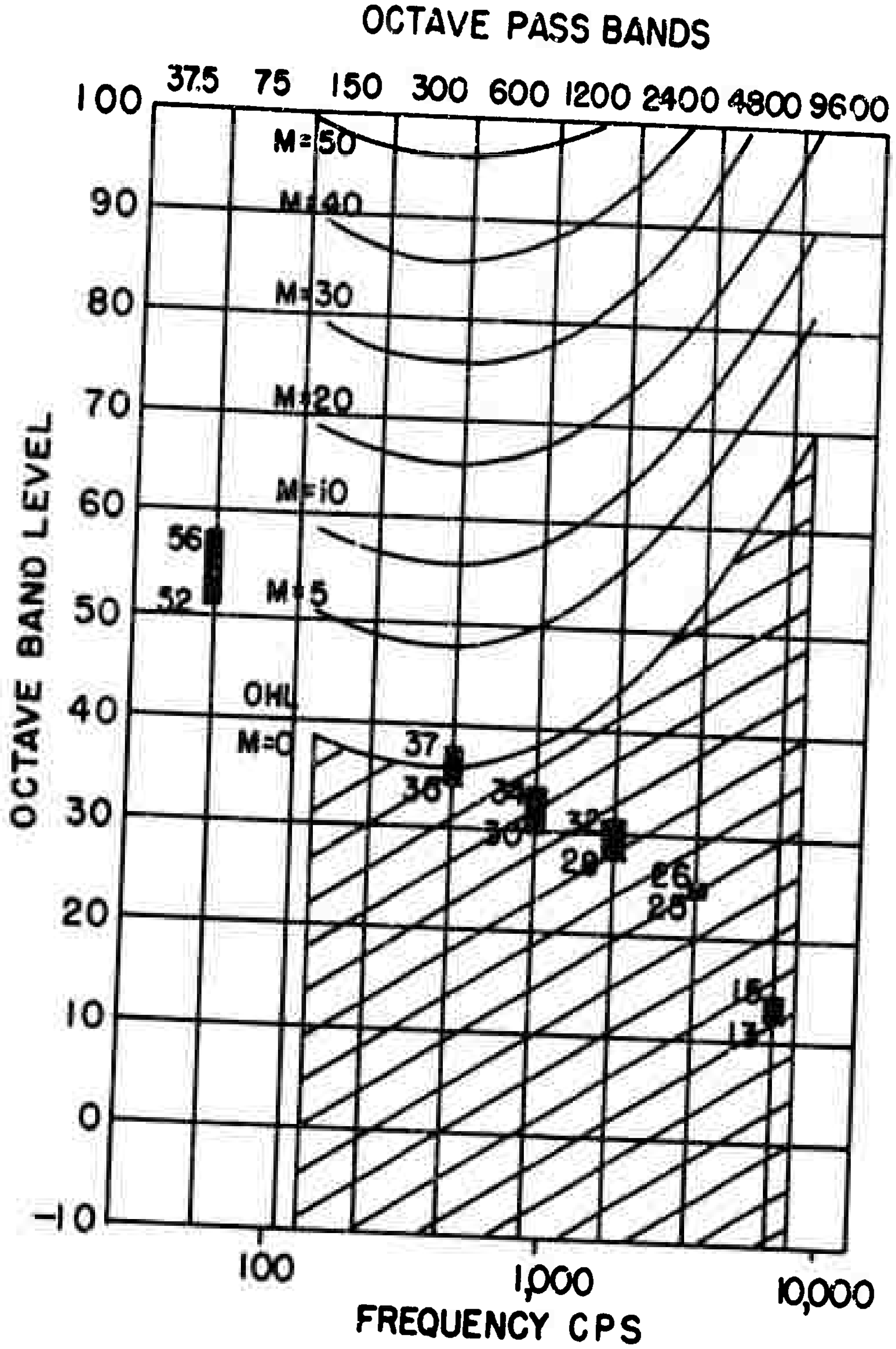


Fig. 2 Ambient noise levels in test environment during testing.

The noise in the 300 to 600 cps octave straddles the contour line* labeled OHL M=5 (zero hearing loss, masking equals five). This indicates that a level of noise as great as this makes it impossible to measure tones at a level corresponding to zero hearing loss, as defined by the American Standards Association. The amount of masking by this noise for a test tone of 500 cps at a level of O HL is little more than one db. At all other frequencies tested, hearing losses of 0 and less could be measured. This analysis indicates that masking due to the ambient noise should not be expected for the test tone frequencies (except at 500 cps as indicated above) used in this study.

## III. RESULTS

The following constituted the basis for the analyses presented in this section: 1) the hearing data questionnaire obtained for each subject, 2) the audiograms that were determined for the right and left ears of each subject, 3) the field sound level survey which furnished the basis of the analysis of the military noise exposure, and 4) the table which was constructed to provide for an analysis of civilian noise exposure.

On the basis of biographical information (age, noise exposure, use of ear protection, etc.) from the hearing data questionnaire, the various personnel were assigned to specific groups for analysis. In determining hearing loss as a function of age, all data sheets were divided into age groups (17-19, 20-29, etc.) then median hearing loss scores were determined for each group. A similar procedure was followed in determining hearing loss as a function of noise exposure (here the field noise measurements were used to fix noise exposure levels), hearing loss for those who did and did not wear ear protection, hearing loss and medical history, etc.

The data were processed on IBM cards and tabulated to determine the first quartile ($Q_1$), the second quartile ($Q_2$), and the third quartile ($Q_3$) to show the hearing loss of the poorest 25% of the hearers, the median, and the best 25% of the hearers respectively, for the categories of age, medical history, noise exposure, etc. All data are expressed in terms of ears because a subject could have one ear which met the criteria for inclusion in a specific group while his other ear did not.

*An explanation of the derivation of these contours can be found in J. C. Webster, "Development and Use of NEL Recorded Warble Tone Hearing Test." Navy Electronics Laboratory, Report 546, 1954. These contours are based upon the Permoflux PDR-8 earphone with donut cushion.

Normative data were screened in order to exclude the data from ears which had a positive medical history. It was not uncommon to find subjects who had had one ear drained, lanced, or had been subjected to surgery, but whose other ear showed no positive medical history. In such a case, the "good" ear was included among the normative data.

Hereafter, data obtained by individual testing will be referred to as Maico data. The group of 706 people whose results were obtained by individual testing, will be called the Maico sample. The sample of 3121 people measured by group testing methods will be called the NEL sample whenever differences in hearing loss are termed "significant" in this report, reference is made to statistical significance only.

A. Hearing Loss as a Function of Age

1. Maico Sample. Frequency distributions of the ages of the 2 samples are presented in Figure 3. This figure shows that the median age of the Maico sample was 23 years, and the age of the NEL sample was 25 years. A possible explanation for the discrepancy between the median ages of the two samples is that examination of the Maico population which was studied first indicated a biased sample of young people. Therefore, a special effort was made to get at least a representative number of the older persons in the NEL sample.

The hearing loss scores of a selected group of ears from the Maico sample were used as a normative group. The ears were those of subjects in the age range 20-29 years who had no previous aural medical history, and had received only negligible exposure to noise. The data from this group are shown in Figure 4-A. The scores shown represent the median loss of all ears at that frequency.

The zero hearing loss reference for audiometers (1) is the modal score at a given frequency of a large number of subjects aged 18-30 inclusive who have "normal" ears. This can be compared with the modal hearing loss scores for the Maico sample from this study which are presented in Figure 4-B. Part of the discrepancy between the Maico zero hearing loss and the results of the normative sample in the present study is resolved by using the modal score as defined by the American Standards Association (ASA) (1), but even so it can be seen that the ASA zero hearing loss is not exactly indicative of what will actually be found in a "normal" group aged 20-29 as defined in this study. It could be that, in spite of the screening technique used, the so-called "normative group" was not based upon "normal" subjects. This "normative group" shows slightly greater hearing losses than would be expected from the ASA norms.

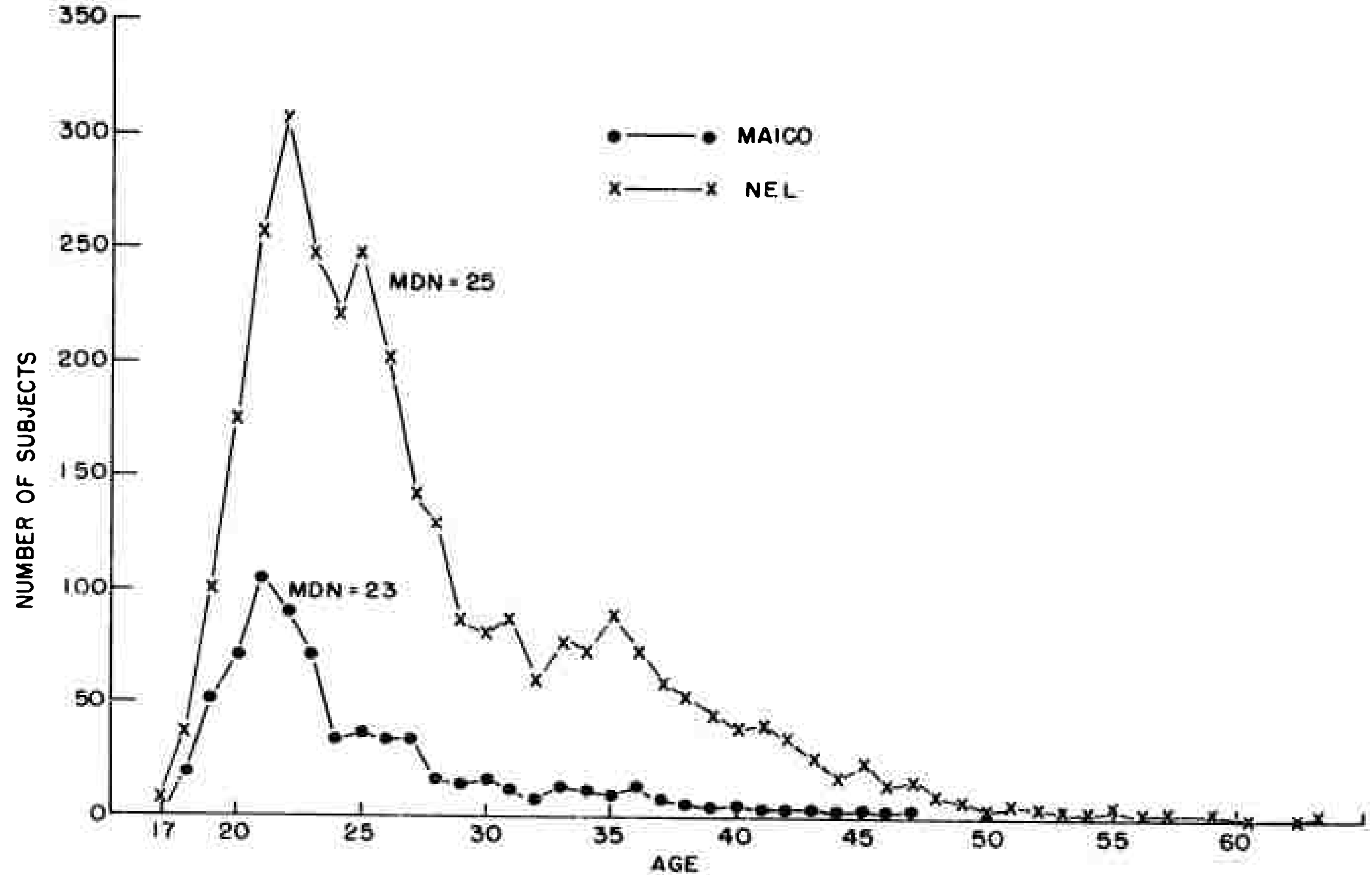


Fig. 3 Frequency distribution of the ages of Maico and NEL subjects.

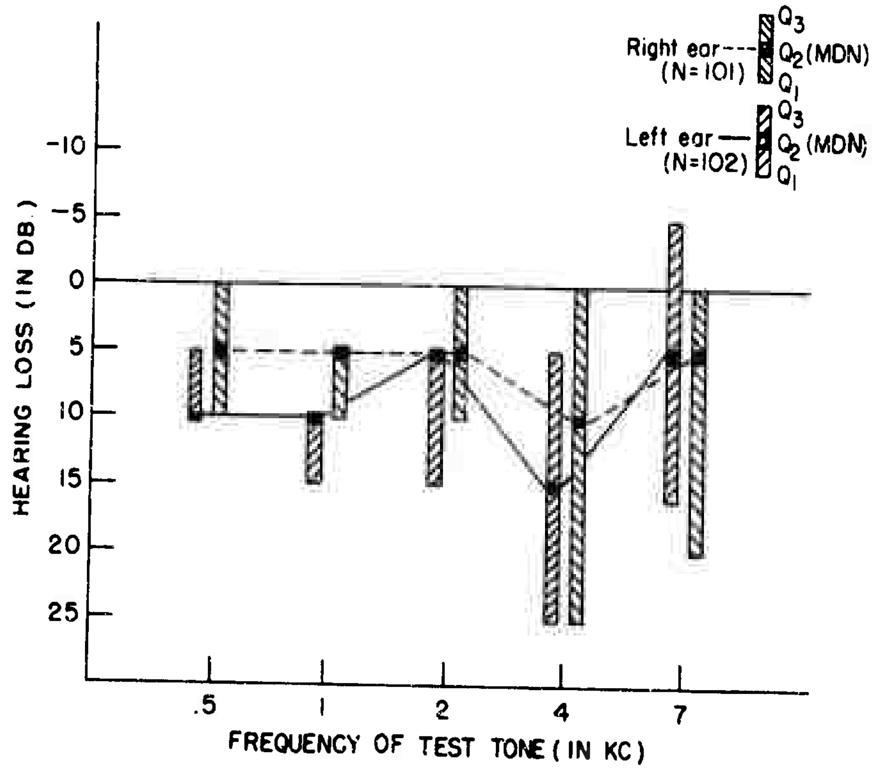


Fig. 4-A Maico normative data. Hearing loss for subjects age 20-29 with no medical history and negligible noise exposure. Skewed distributions frequently result in the median falling within the same interval as either the $Q_1$ or the $Q_3$. Notice, for example, at .5 KC above that $Q_1$ and $Q_2$ both have a value of 10 db H. L. for the left ear.

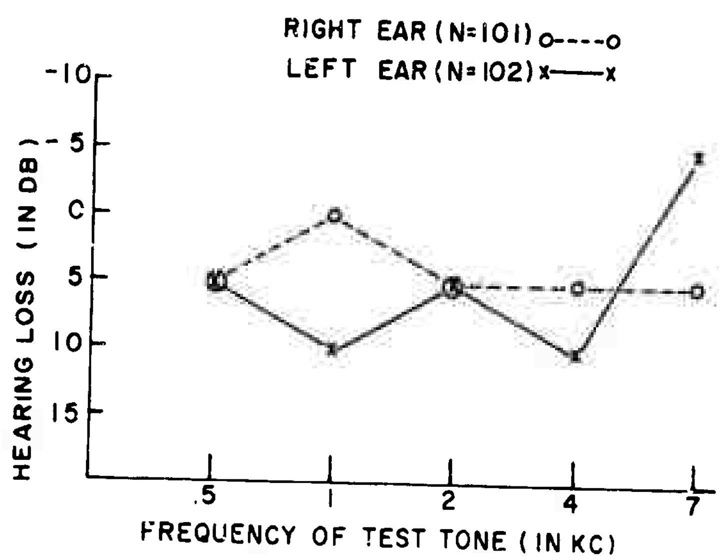


Fig. 4-B Maico normative data (Modal hearing loss). Hearing loss for subjects age 20-29 with no medical history and negligible noise exposure.

As expected, hearing losses for high frequencies were found to increase rather sharply among older subjects. The hearing losses of the Maico sample for ages 17-19, 20-29, 30-39, and 40-49 including all ears, regardless of previous noise exposure and/or medical history, are shown in Figure 5.

The right and left ears of the subjects in the Maico group were found to differ significantly, with the right ear consistently better than the left ear. The difference between the two ears was analyzed across age groups by means of the paired-replicates test (10) and was significant beyond the 1% level of confidence.

The audiometers used in this study were calibrated immediately before beginning the study and were checked at the end of the study. The earphones of the audiometers were all found to be matched within one db throughout the frequency range of the test tones. Therefore, the difference between ears is not attributable to differences in the earphones. This finding substantiates that of Dr. Glorig* with his 1954 Wisconsin State Fair Survey. His results "... show a statistically significant difference between the right and left ear. The right ear being the better ear." The differences found in this study are in the same direction, but could be due to the fact that the left ear was tested first. One might assume that the better performance with the right ear could be due to increased familiarity with the task.

2. NEL Sample. The age distribution of the 3121 subjects tested by the NEL group hearing test is shown in Figure 3. The median age of the NEL group was 25 years.

The base line for the NEL group was established by selecting persons in the age group 20-29 who had negligible noise exposure and no previous aural medical history and determining their median hearing loss. This median loss was then used as the reference point for all hearing losses and defined the "zero hearing loss" for this study. This procedure is commonly referred to as the "biological baseline" technique (8).

*Personal communication from Dr. Aram Glorig, Director of Research for the Research Center of the Subcommittee on Noise in Industry of the Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology.

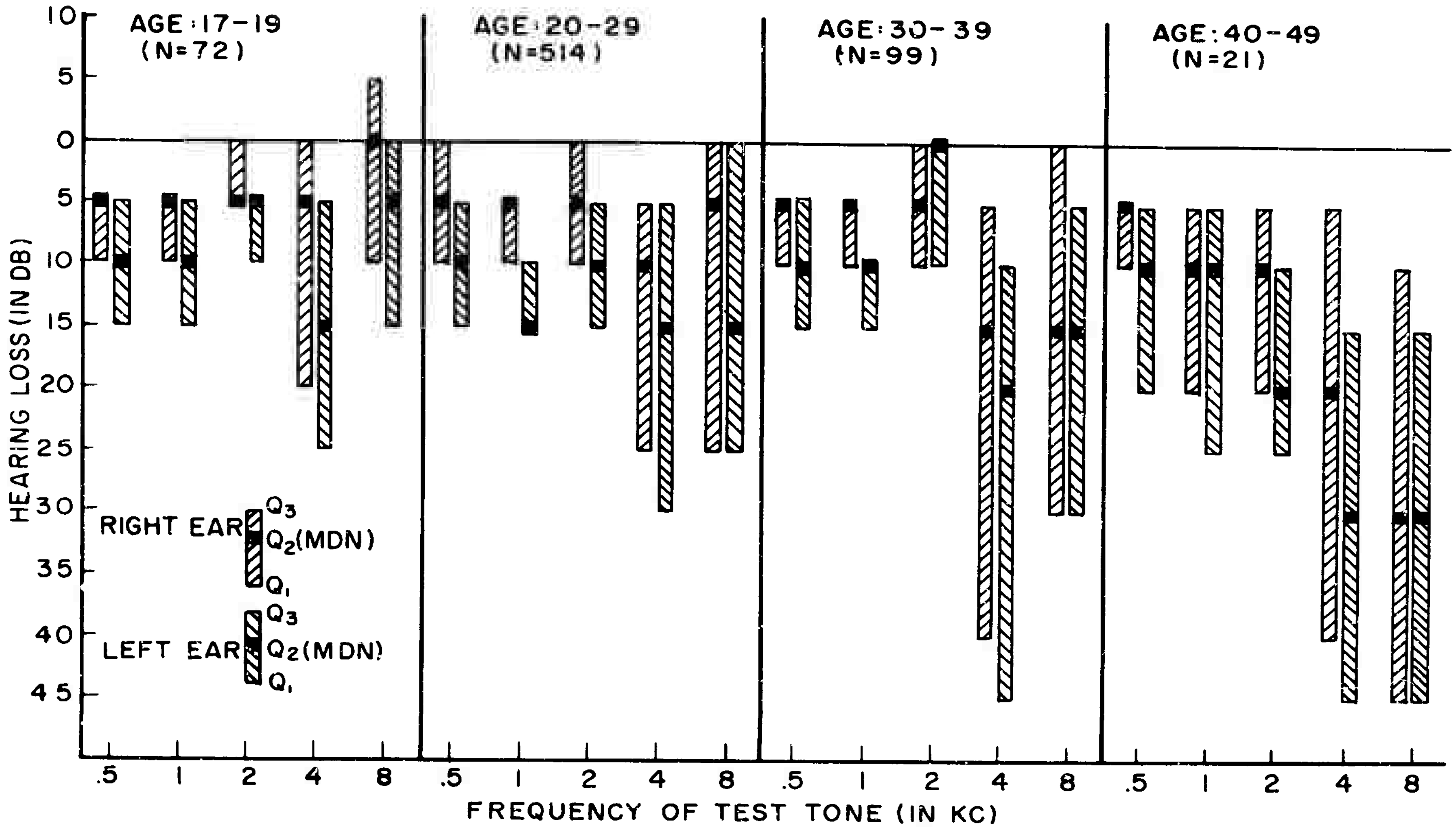


Fig. 5 Hearing loss as a function of age. (Maico data).

The NEL normative data are shown in Figure 6. The group upon which these data are based is comparable to the normative groups cited in Steinberg et al, (5), Webster et al, (6) and Webster and Solomon (7).

Although the objectives of this study did not require that the data be corrected for presbycousis, such a correction could be made if desired. The hearing loss due to aging would presumably be indexed by that loss exhibited by individuals of a given age with negligible noise exposure and no positive aural medical history.

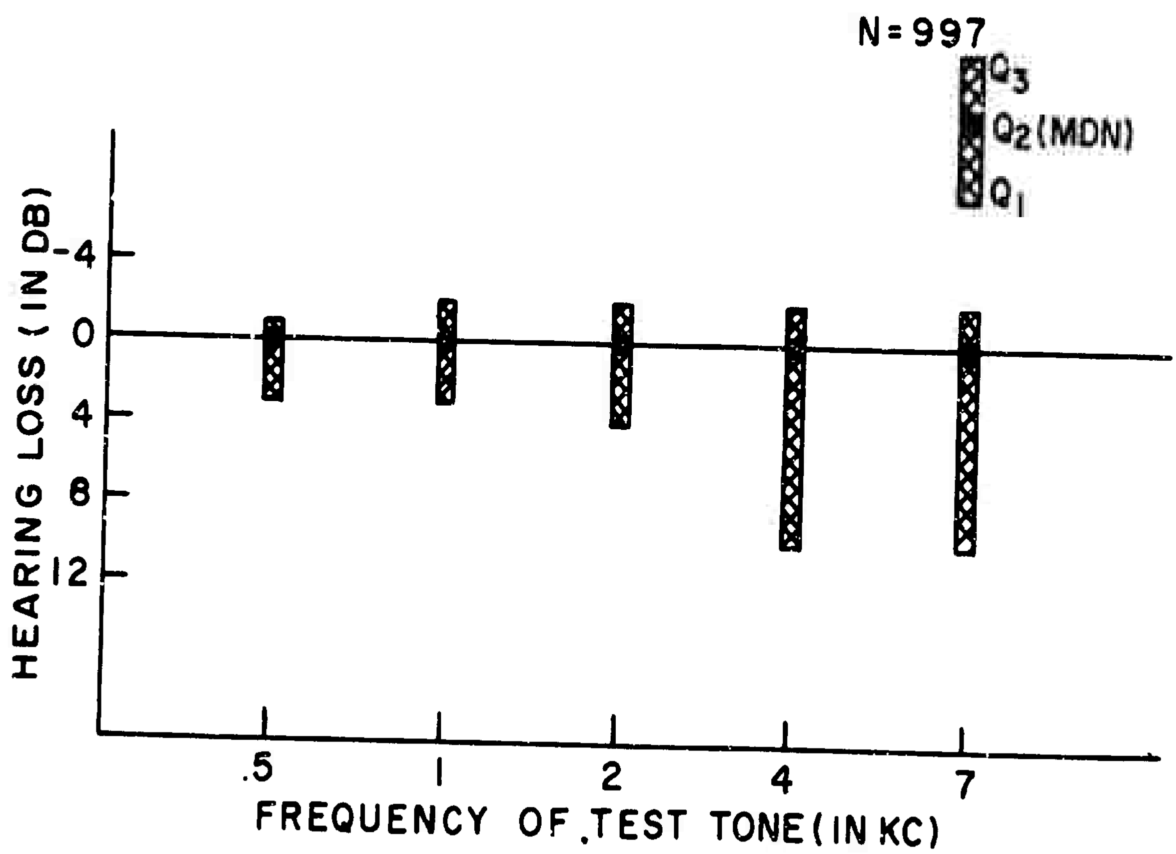


Fig. 6 Normative data, NEL (Hearing loss for age 20-29, no medical history, negligible noise exposure.)

Hearing losses for the different age groups are shown in Figure 7. In the analysis of the NEL sample, the hearing losses from the right and left ears were not found to differ significantly. Therefore, the data from the right and left ears were pooled. A possible explanation for the lack of a difference between the left and right ears in the NEL data is that all subjects had a short preliminary training period in the use of the method. Also, each threshold in each ear was based upon a total of 25 signals, thereby giving the subjects more experience in attending; that is, 125 signals for the NEL test for the audiogram on each ear versus approximately 30 signals for the audiogram on each ear for the Maico. This could possibly minimize the influence of learning upon the hearing loss results even though the left ear was always tested first in the NEL procedure as it was in the Maico procedure.

It is evident from Figure 7 that, with the exception of the 17-19 year age group, hearing losses increase with age. Steinberg et al (5) found that their youngest age group (10-19) from the World's Fair data had slightly poorer hearing than that of the next older group (age 20-29, as in the NEL data). These workers believe that their results are due to the greater difficulty experienced by the younger persons in understanding the test instructions. This explanation would not hold for the 17-19 age group in the NEL portion of the present study. No reason is immediately apparent for the slightly poorer hearing of the 17-19 age NEL group as compared to the 20-29 group. However, the difference is a small one, no more than 2 db at any frequency, and is not statistically significant. A difference this small would not be revealed by the usual audiometric procedures and hence should at most be considered indicative of a trend.

## B. Hearing Loss as a Function of Noise Exposure

The analysis of hearing loss as a function of noise exposure could be done in a meaningful way only upon the NEL sample due to the small size of the N in the Maico portion of the study.

Figure 8 presents a graphical comparison of the hearing losses of the negligibly and severely exposed subjects of each of the age groups included in the NEL data. The median hearing loss for each age group by frequency and noise exposure, including those moderately exposed, appears in Table 4.

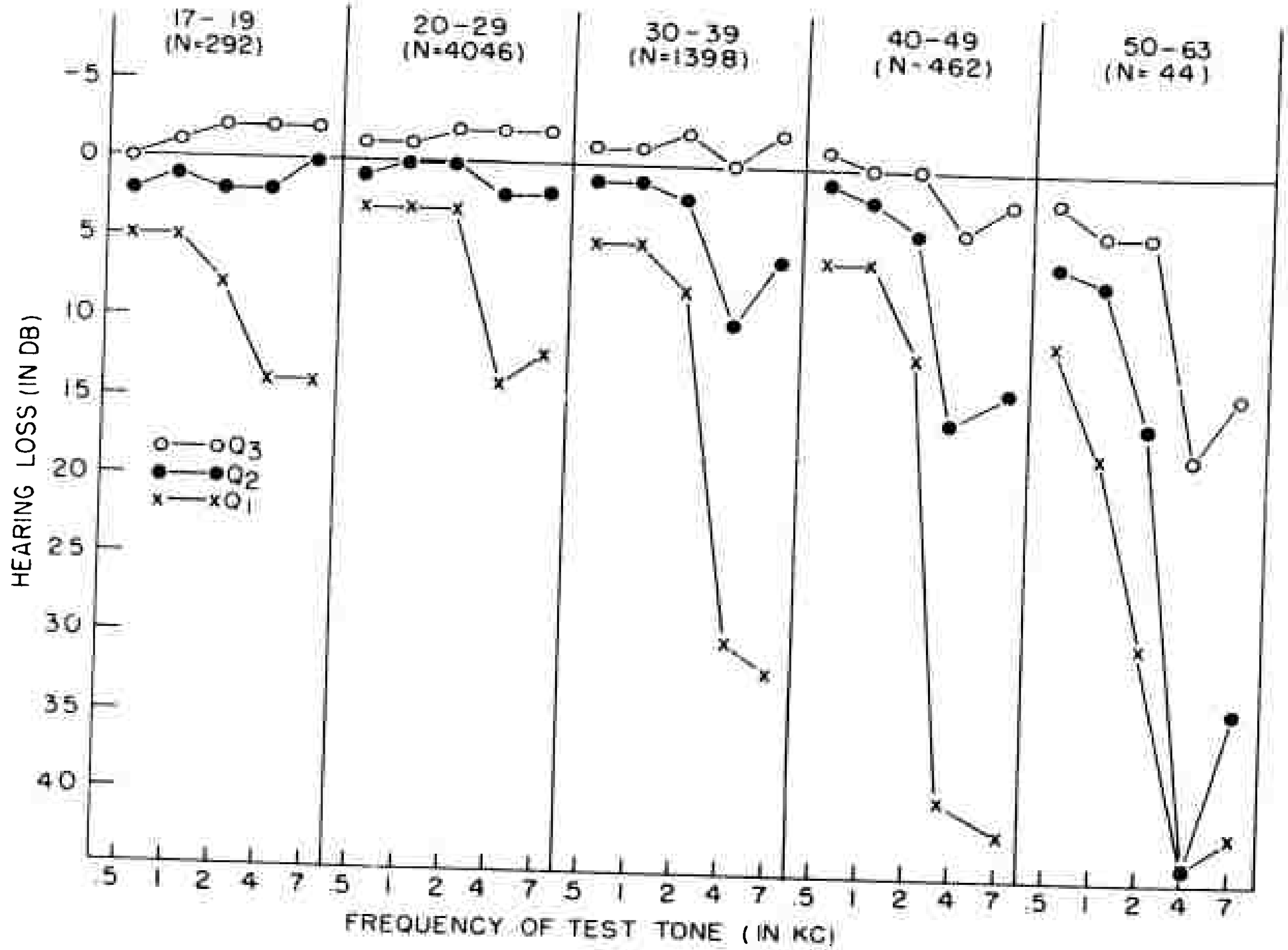


Fig. 7 Hearing loss as a function of age. (NEL data)

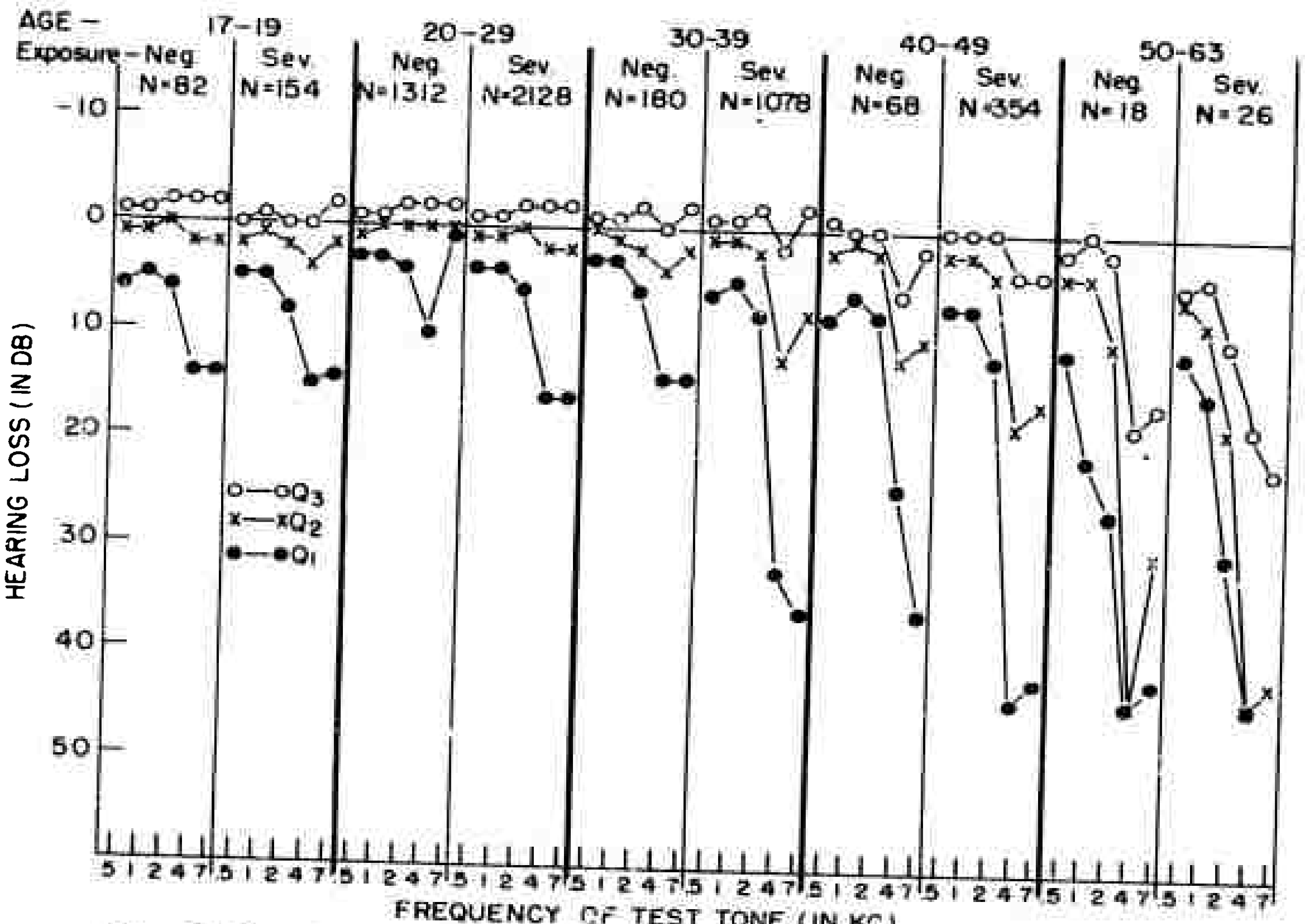


Fig. 8 Hearing loss as a function of noise exposure. Note: Q values of 44 db hearing loss (HL) represent a minimum estimate. The testing procedure did not allow determination of HL values greater than this at 4 KC and 7 KC.

TABLE 4

HEARING LOSS AS A FUNCTION OF AGE AND NOISE EXPOSURE

| Exposure | Test Tone Frequency | Age 17-19 | 20-29 | 30-39 | 40-49 | 50-63 |
|---|---|---|---|---|---|---|
| Neg | 500 cps | 1 | 1 | 0 | 2 | 4 |
| Mod | | 1 | 1 | 2 | 0 | - |
| Sev | | 2 | 1 | 1 | 2 | 6 |
| Neg | 1000 cps | 1 | 0 | 1 | 1 | 4 |
| Mod | | 0 | 1 | 2 | 0 | - |
| Sev | | 1 | 1 | 1 | 2 | 8 |
| Neg | 2000 cps | 0 | 0 | 2 | 2 | 10 |
| Mod | | 0 | 0 | 4 | 0 | - |
| Sev | | 2 | 0 | 2 | 4 | 18 |
| Neg | 4000 cps | 2 | 0 | 4 | 12 | 44* |
| Mod | | 2 | 2 | 10 | 10 | - |
| Sev | | 4 | 2 | 12 | 18 | 44* |
| Neg | 7000 cps | 2 | 0 | 2 | 10 | 30 |
| Mod | | 0 | 0 | 6 | 4 | - |
| Sev | | 2 | 2 | 8 | 16 | 42 |
| | Neg (N** = | 82 | 1312 | 180 | 68 | 18 |
| | Mod (N** = | 54 | 606 | 140 | 40 | 0 |
| | Sev (N** = | 154 | 2128 | 1078 | 354 | 26 |

Values in body of table are Median Hearing Loss in db (re:.0002 microbar).

*Represents a minimum estimate.
**N here is expressed as the number of ears rather than the number of subjects.

The differences in hearing loss between the negligible and severe exposure cases in the two youngest age groups (17-19, 20-29) although small, were significant and in the expected direction. Examination of Figure 8 shows that hearing loss differences between the negligibly and severely exposed subjects grow increasingly larger as the age of the subjects increases, especially at the higher frequencies. This result is subject to at least two interpretations: 1) younger ears are more resistant to noise induced loss; or 2) the cumulative effects of noise exposure result in older persons suffering more loss. Both of the above hypotheses could be correct, with each of these factors contributing to the data simultaneously.

Figure 8 also shows that the poorest 25% (or $Q_1$'s) of the severely exposed older subjects (excluding the age 50-63 group) have less acute hearing, proportionally, than those of the negligibly exposed older subjects; most markedly so at 4000 and 7000 cps. The best 25% (or $Q_3$'s), however, do not differ significantly for age groups 17-19 through 40-49. This indicates that we can expect even greater losses at the poorest end of the distribution of hearing losses than the differences in median losses would lead us to expect.

## C. Hearing Loss With and Without Ear Protection

Subjects in the NEL sample were screened on the basis of their answer to the question on the hearing data sheet regarding the use of ear protection. They were separated at first into two groups, those who had worn any type of ear protection against noise and those who had "never" worn protection.

A paired-replicates test revealed that there was no statistically significant difference between these two groups with regard to hearing losses. It was felt, however, that differences might appear if the groups were further sub-divided on the basis of age and previous noise exposure. This division was accordingly made and a similar paired-replicates analysis was done to see if hearing losses differed significantly for those who did and did not wear ear protection in the 20-29, 30-39, and 40-49 year age groups. Becuase of the relatively small number of persons in the age 17-19 and age 50 and over groups, they were not included in these analyses on the effect of ear protection. The hearing losses of those in the 20-29 and 30-39 year age groups who did wear ear protection were found to be significantly larger (at the 5 per cent level of confidence) than those in the group who did not wear ear protection. When the hearing loss differences in the 40-49 year group were tested, they were found not to differ significantly. The differences in the 20-29 and 30-39 age groups, are not in the direction one would expect. This will be discussed more fully below.

A further analysis was made by dividing those who did and did not wear ear protection into noise exposure groups, then testing for the significance of the differences in hearing losses among the three groups. The paired-replicates test showed that the differences in hearing losses between those who did and did not wear ear protection were not significant for ears negligibly or moderately exposed to noise. This is according to expectation. The differences were statistically significant for those who were severely exposed to noise, but this difference was not in the expected direction. Severely exposed ears which had protection tended to show greater losses than those ears which did not have protection. This information, combined with the analysis-by-age data above, shows that individuals who are 20-29 or 30-39 years of age and whose ears have been severely exposed to noise tend to show slightly greater hearing losses if they have used ear protectors than if they have not.

Figure 9 presents a graphical summary of the data relating hearing loss to age, previous noise exposure, and the wearing of ear protection.

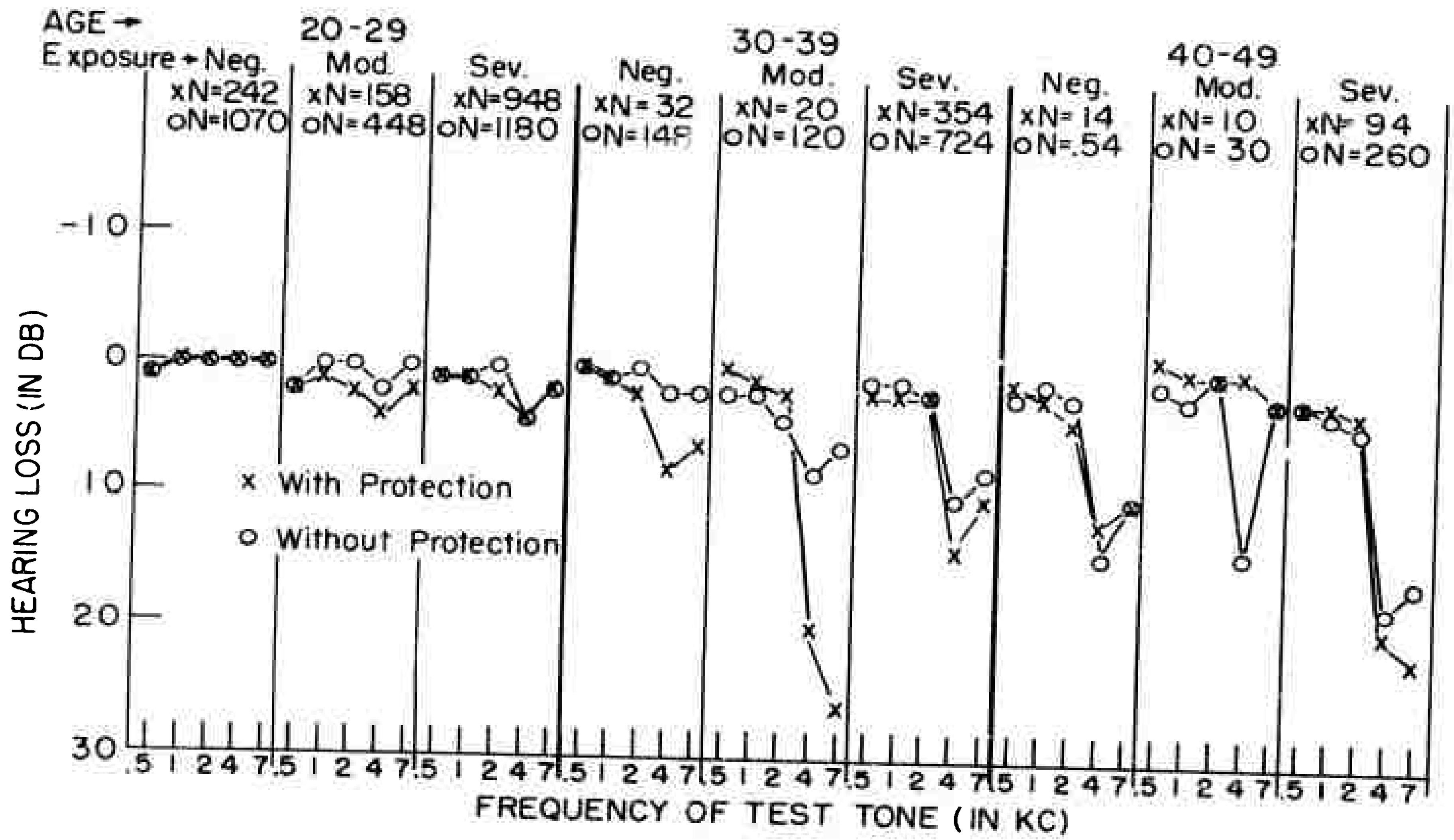


Fig. 9 Hearing loss as a function of age and use of ear protection.

Superficially, the finding that wearing ear protection leads to greater hearing losses would appear to be absurd, but there are some possible explanations for this result. It was felt that the frequency-of-usage categories "frequently" and "seldom" were somewhat ambiguous and not similarly interpreted by all subjects. Therefore, the data were re-analyzed, comparing now only those who indicated that they "never" wore protection with those who "always" wore protection. The results of this analysis, however, did not reverse the direction of the differences and the paradox remained.

Two alternative explanations are here presented: 1) even though the ear protection worn by some of the severely exposed individuals may attentuate the noise as much as 20 db, if these individuals are in extremely loud noise, such as 140 db, their ear protection will not bring them down to noise exposure levels comparable to those not wearing protection who work around noise of 110 db; 2) possibly those who used ear protection did so only after aural stimulation became painful and/or hearing losses had already appeared, whereas those who did not wear ear protection were more resistant to noise induced hearing loss and did not feel the need to wear ear protection, i.e., stimulation was not actually painful, nor did their ears ring annoyingly after exposure. If exact exposure levels and durations of exposure had been available for every subject, more precise noise exposure judgments could have been made. Undoubtedly, more exposure levels could have been discriminated, and quite possibly this paradox of larger losses with ear protection than without would not have appeared.

### D. Hearing Loss and Medical History

An analysis was made of the differences in hearing losses of the subjects who answered "yes" to any of the first four questions in the medical history section of the hearing data sheet. Those who answered "yes" to any or all of the first four questions were said to have a positive medical history; those who answered "no" to all of the question, a negative medical history. The losses of those who answered "yes" were then compared with the losses of those who answered "no". The $Q_1$, $Q_2$, and $Q_3$ hearing loss values for those with positive and negative medical histories in the NEL sample are shown in Figure 10. The trend, as shown in Figure 10, seems to be for median hearing losses to be greater for those who have a positive medical history. However, the number of points (5) was too small to permit a paired-replicates test of the significance of the hearing loss differences between the "yes" and "no" populations. When the same analysis of hearing loss as a function of medical history was made on the Maico data, it was found that ears

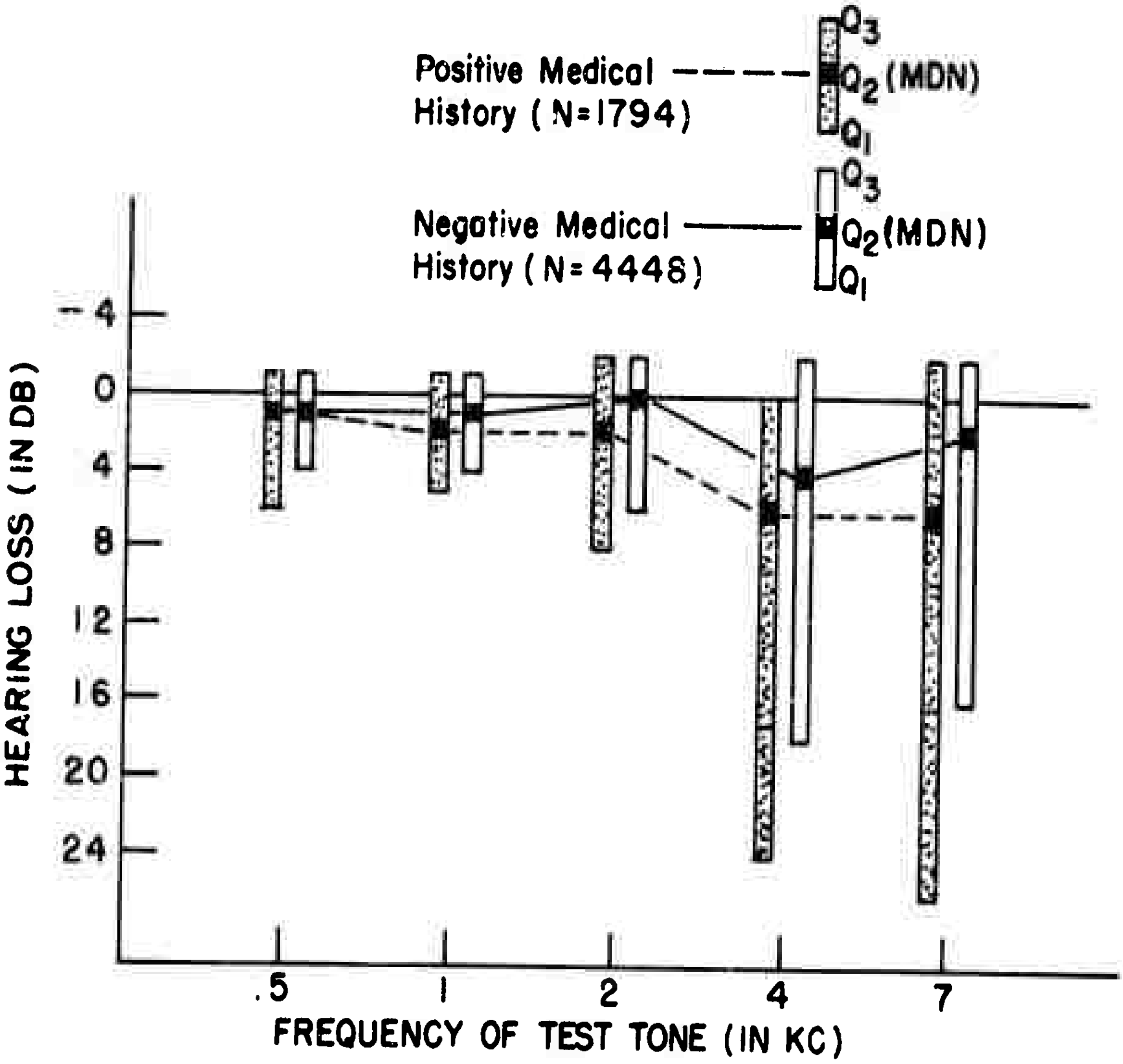


Fig. 10 Relation between median hearing loss and medical history. (NEL sample)

with a positive medical history had statistically significantly greater hearing losses than ears which did not have a medical history. The Maico results are shown in Figures 11-A and 11-B. These results are in close agreement with those obtained in the NEL portion of the study.

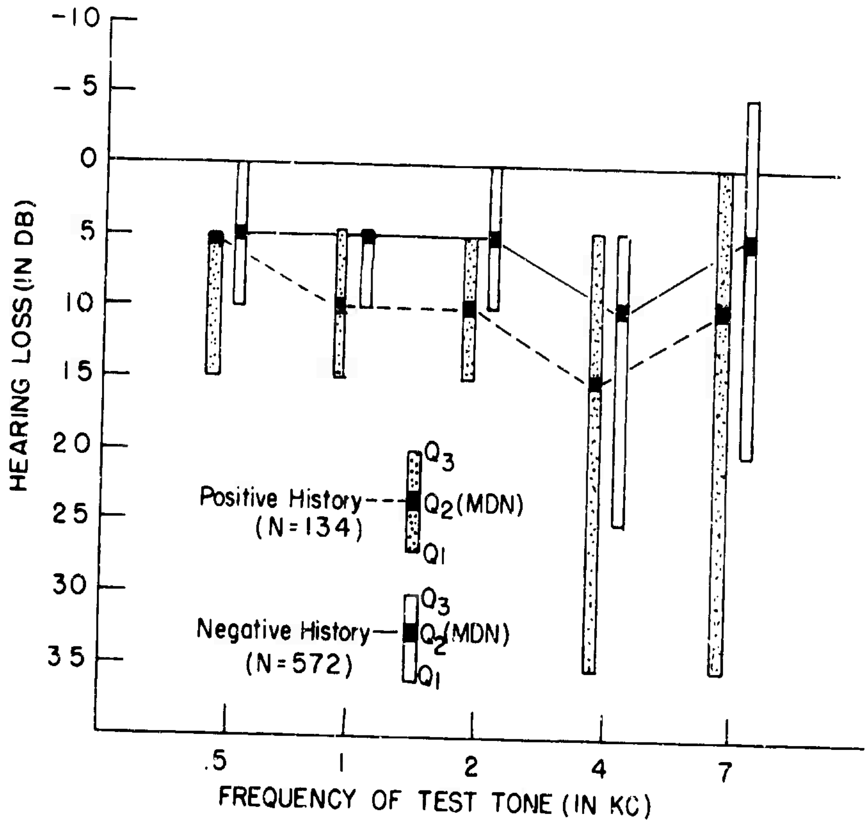


Fig. 11-A Relation between positive or negative medical history and median hearing loss: Right ear. (Maico data)

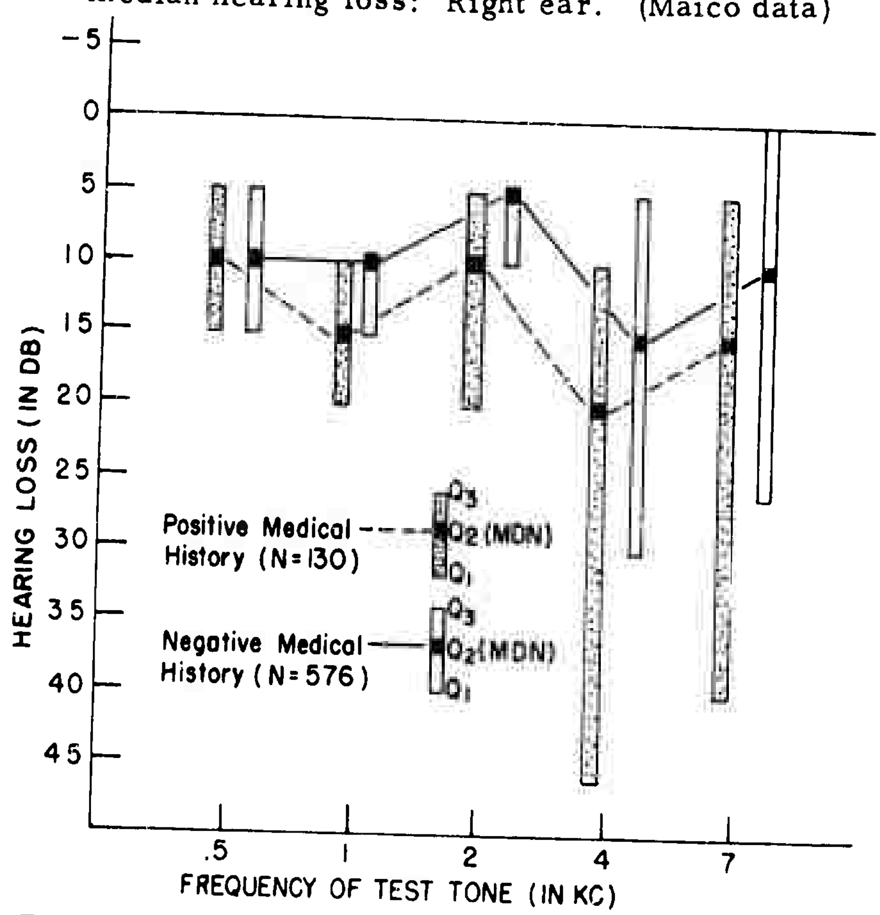


Fig. 11-B Relation between positive or negative medical history and median hearing loss: Left ear. (Maico data)

An analysis was made of the hearing loss differences found among those who had experienced tinnitus while in a quiet place prior to exposure to loud noises or gunfire and those who had not had such "pre-exposure" tinnitus. The information necessary for this analysis was secured from the subject's answers to question 5 in the medical history section of the hearing data sheet and from their audiometric data.

Results for the NEL sample who indicated they had experienced tinnitus in a quiet place without having previously been exposed are inconclusive. A trend is evident for those who experience tinnitus prior to exposure to have larger hearing losses but, because there were only 5 points, the paired-replicates test for significance could not be used. The NEL results are shown in Figure 12. A similar analysis was made of the MAICO data (see Figure 13-A and 13-B) and showed that those who had a history of tinnitus prior to noise exposure had significantly higher hearing losses. The paired-replicates test for significance could be used with these data because there were 10 points plotted.

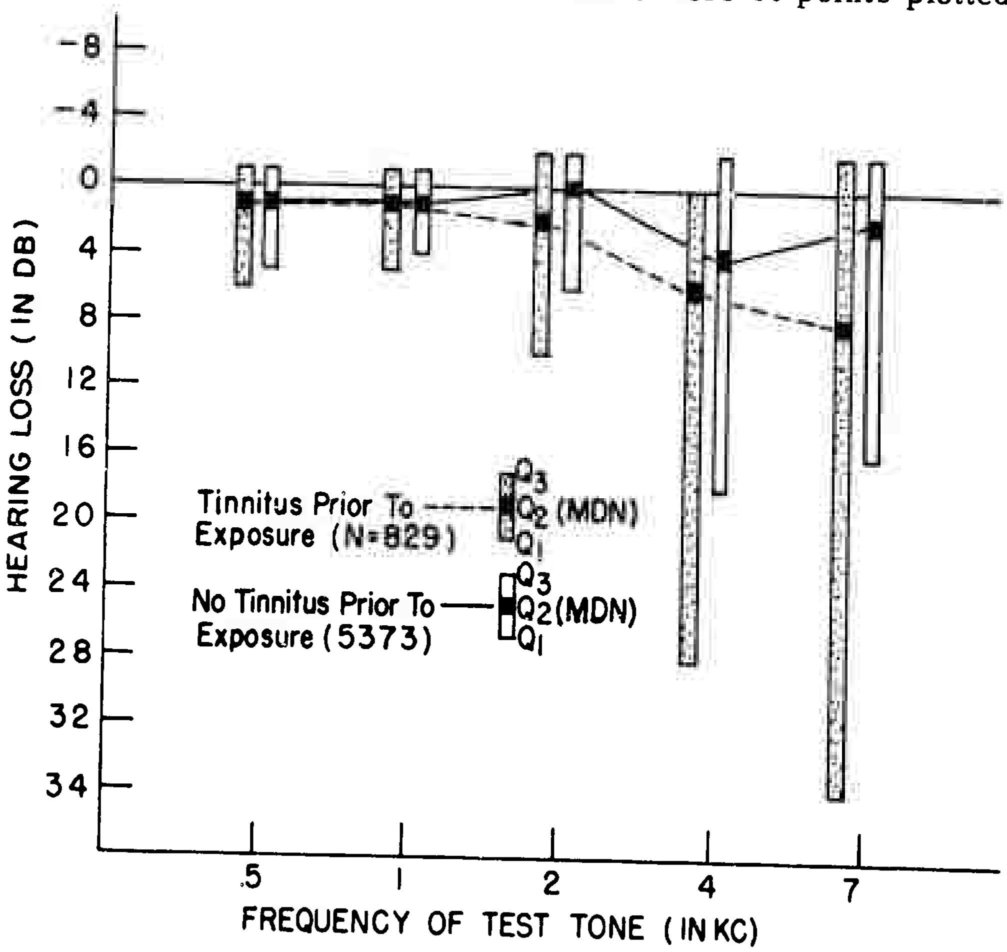


Fig. 12 Relation between median hearing loss and tinnitus prior to exposure.

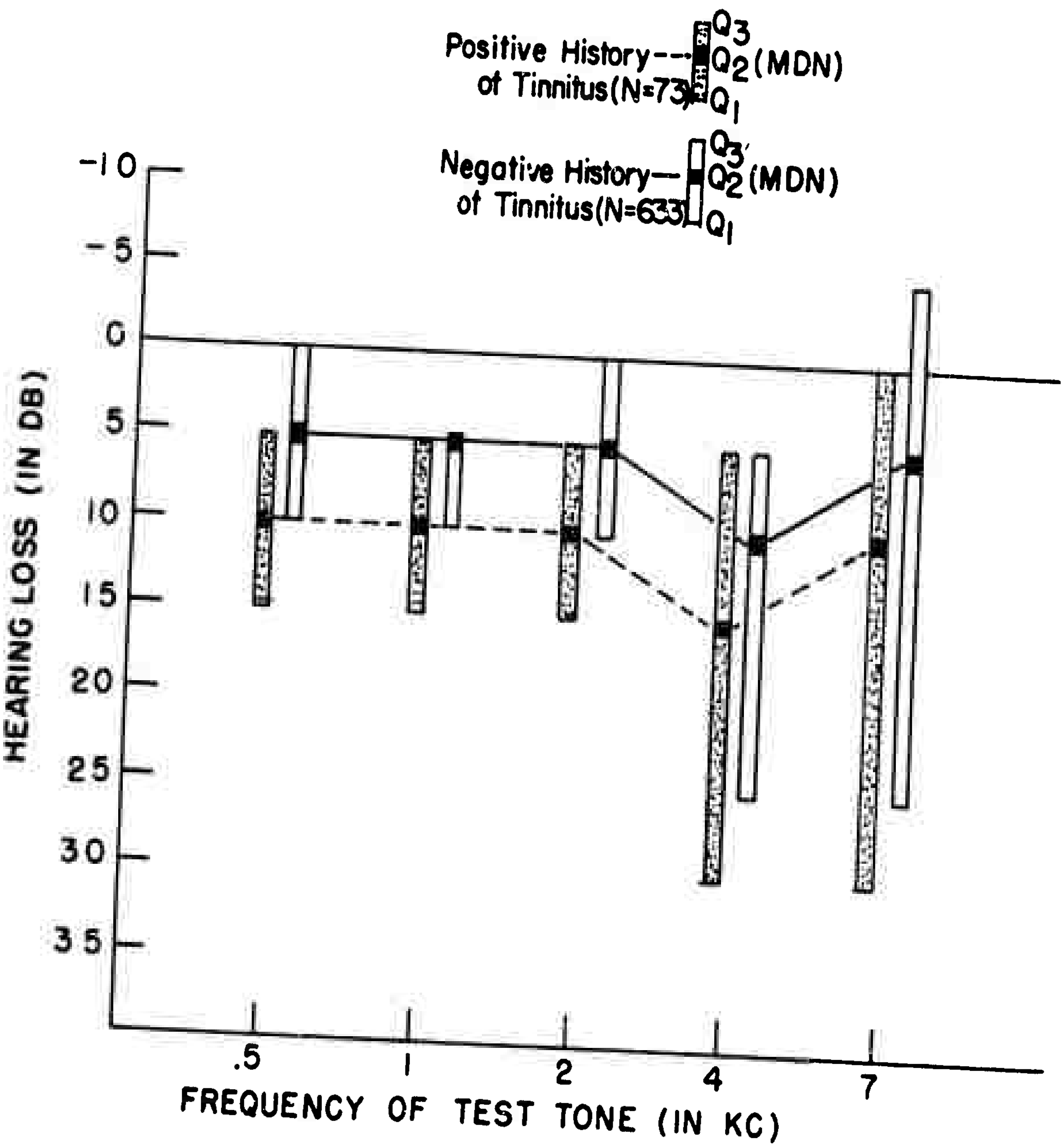


Fig. 13-A Relation between median hearing loss and tinnitus prior to loud noise exposure: Right ear.

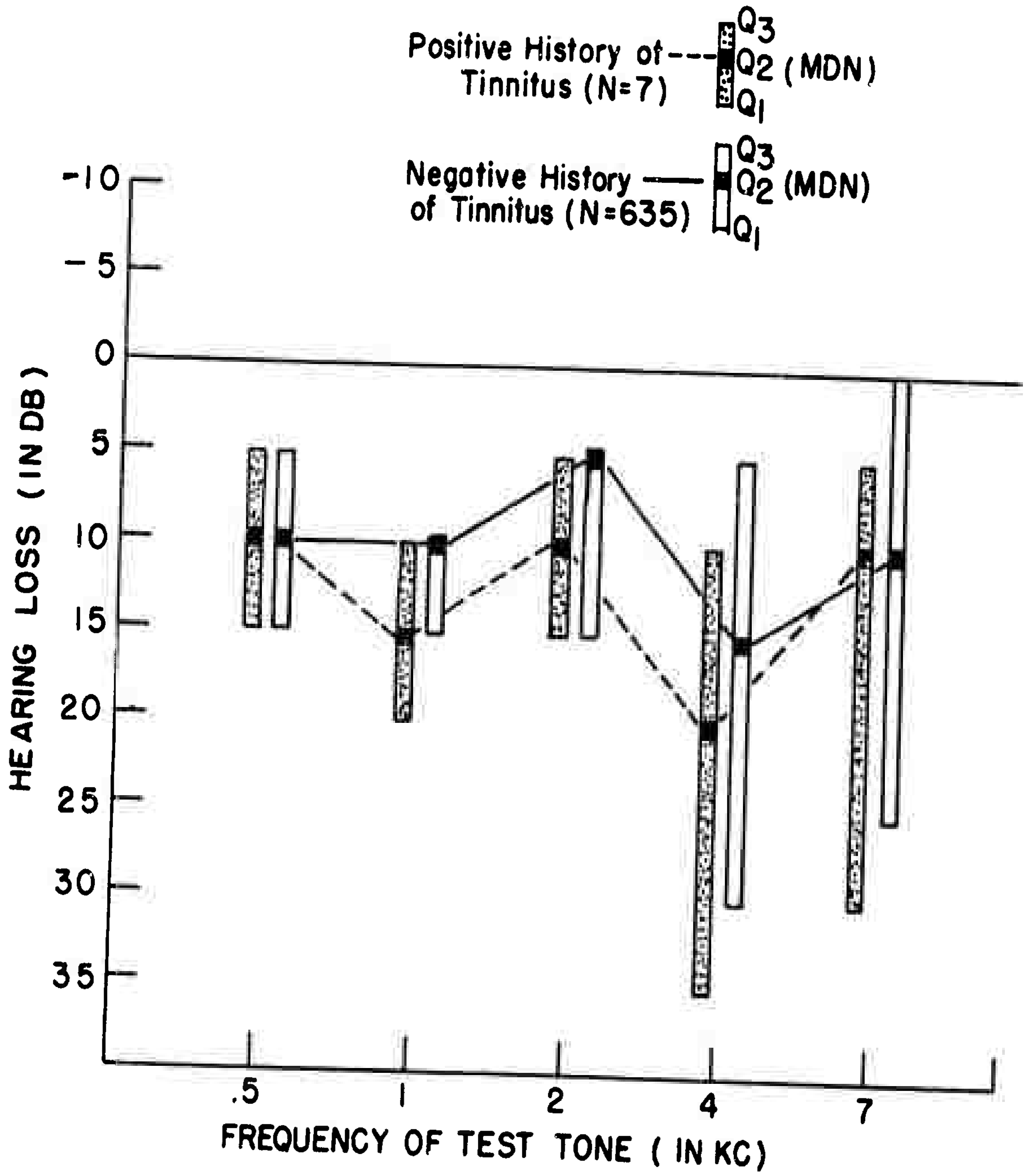


Fig. 13-B Relation between median hearing loss and tinnitus prior to loud noise exposure: Left ear.

The data were sorted and hearing loss scores were tabulated on the basis of the subject's answers to question 6, on the medical history section of the hearing data sheet regarding tinnitus following first exposure.

Figure 14, which presents the NEL data, shows that subjects whose tinnitus persisted for longer than an hour had larger hearing losses than did those whose tinnitus did not last as long. The significance of this trend was tested by dividing the tinnitus data into age groups and making the paired-replicates test. The differences in hearing losses between those whose tinnitus persisted and those whose tinnitus did not persist were significant at the 1 per cent level of confidence. Figures 15-A and 15-B reveal the same trend in the Maico data that was shown in the NEL data. Those subjects whose tinnitus lasted for longer than an hour had significantly greater losses than did those who either did not experience tinnitus or whose tinnitus did not last as long. The results of this alanysis of hearing losses of those who experience pre-exposure or prolonged post-exposure tinnitus suggest that personnel who experience this phenomenon in this manner may be more susceptible to noise induced hearing loss and perhaps should be kept out of high noise level environments.

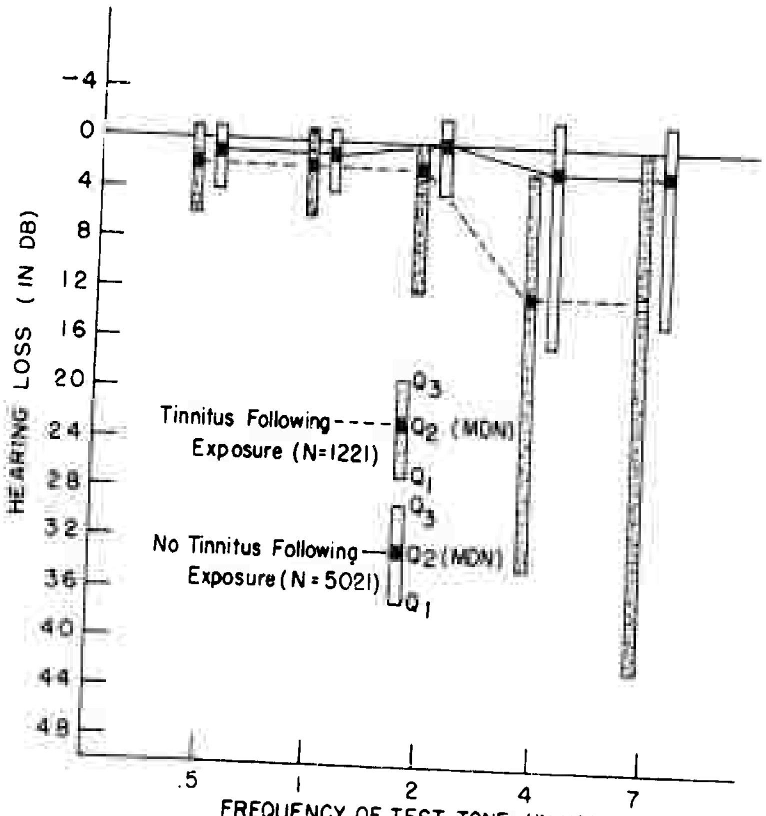


Fig. 14 Relation between median hearing loss and post exposure tinnitus.

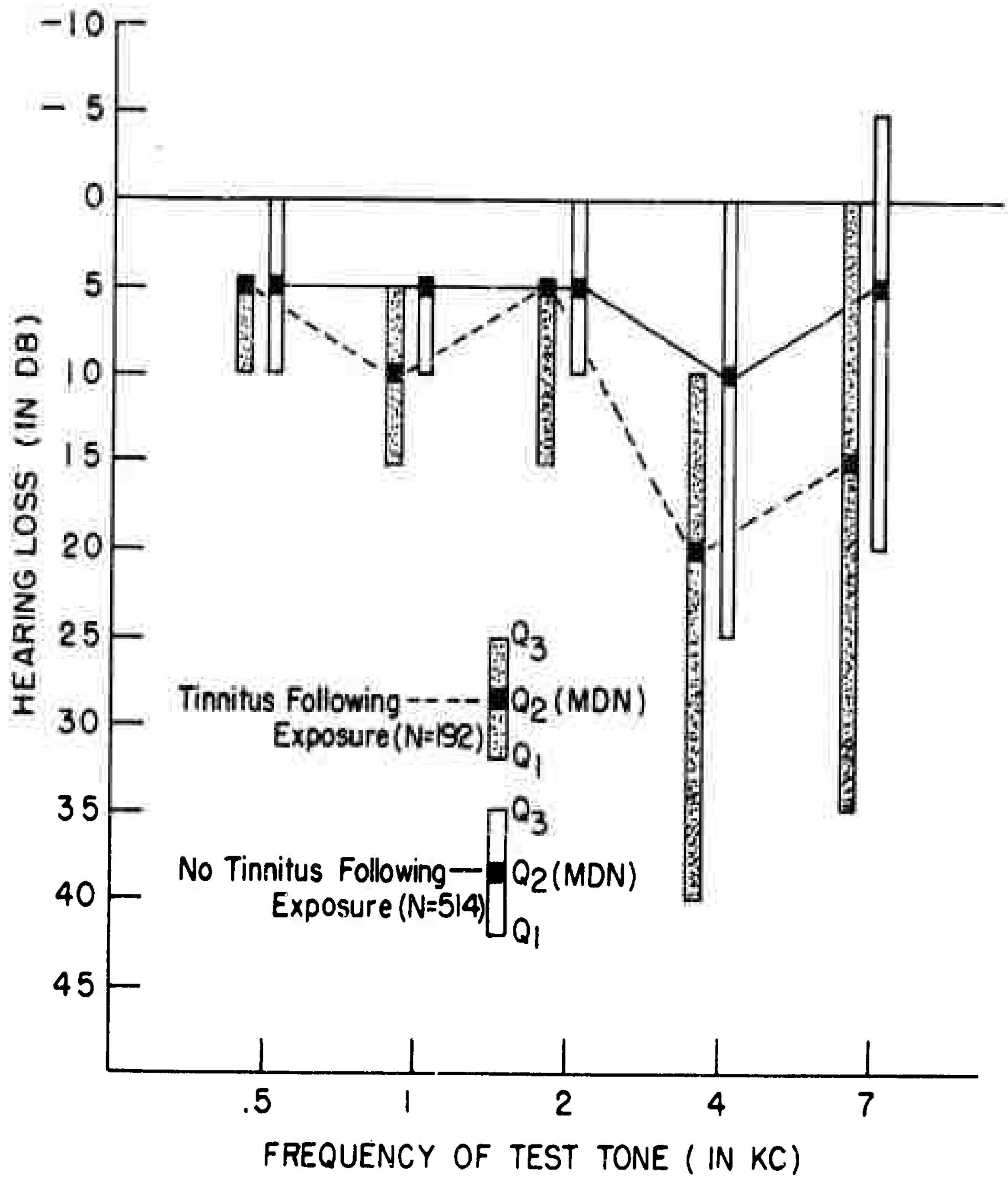


Fig. 15-A Relation between median hearing loss and tinnitus following loud noise exposure: Right ear.

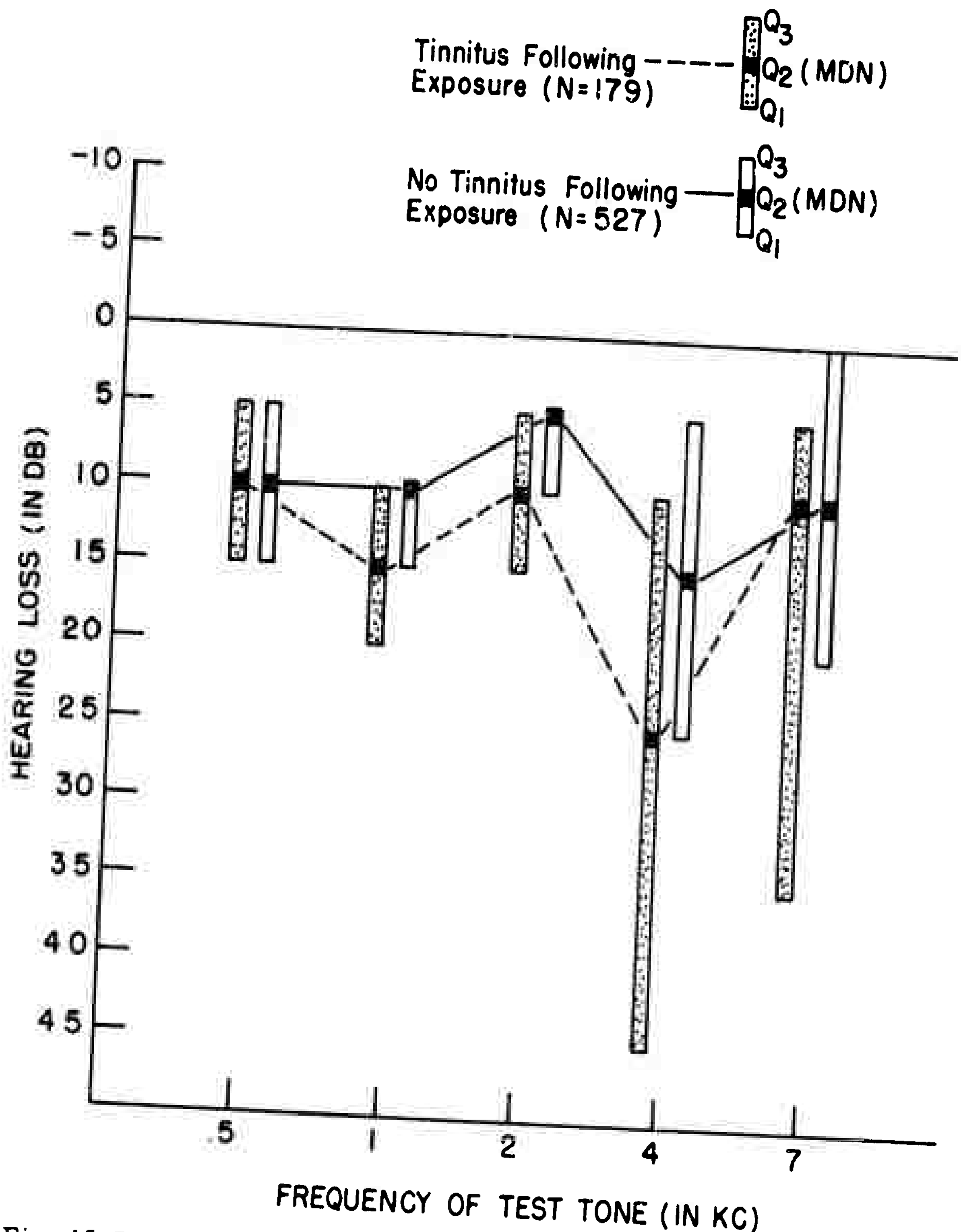


Fig. 15-B Relation between median hearing loss and tinnitus following loud noise exposure: Left ear.

E. Hearing Loss and Type of Ear Protection

Under the Type of Protection section, the subjects who used ear protection marked the type of ear protection they utilized. The first three listed types of ear protection were worn internally (i.e., inside the ear); the last three types of protection were worn outside the ear. The hearing losses of those who wore internal ear protection were compared with the hearing losses of those who wore external protection. Figures 16-A and 16-B present the results obtained with the Maico groups. The hearing loss differences between the internal and external ear protection groups were tested with the paired-replicates test and found not to differ significantly.

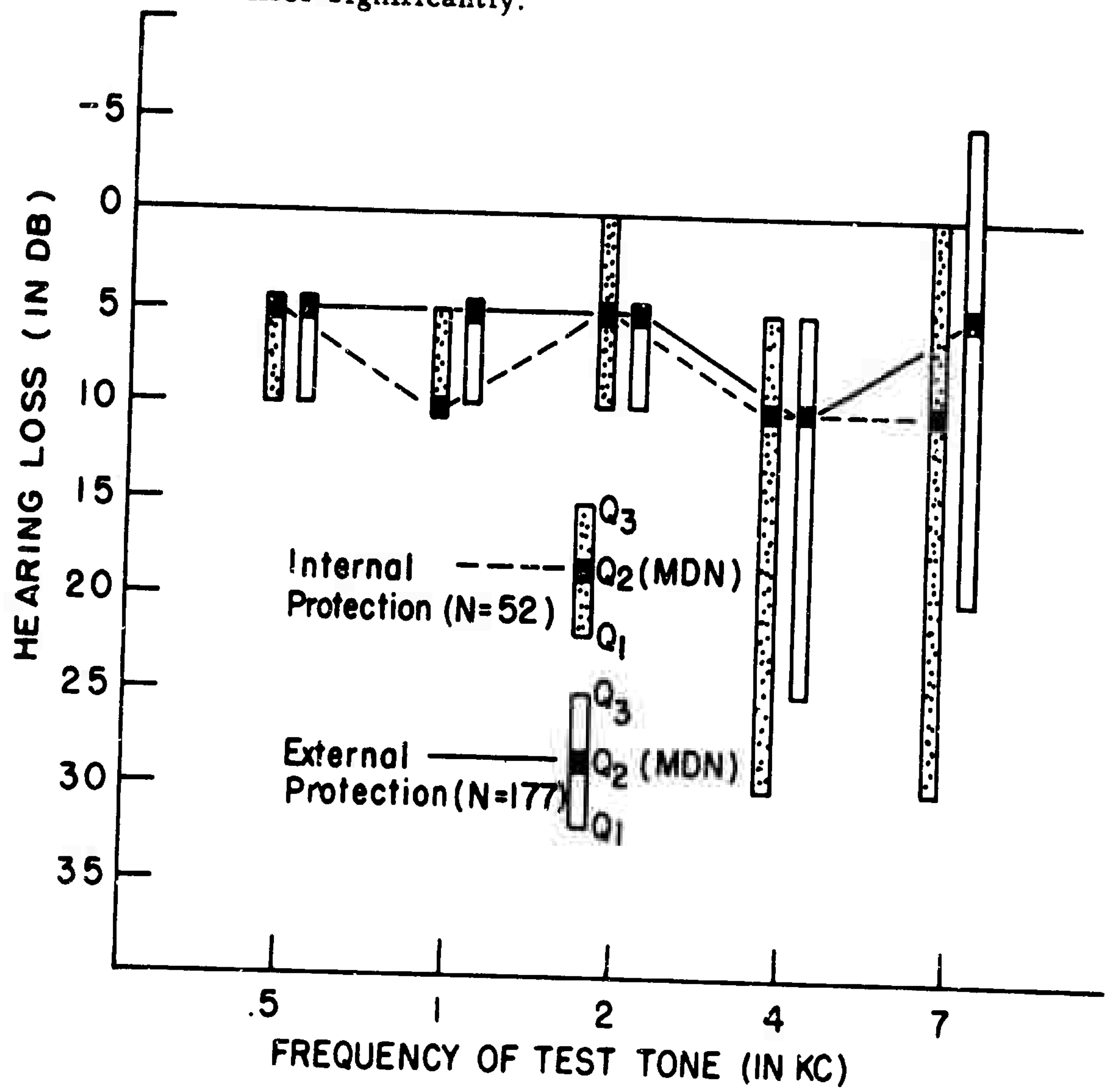


Fig. 16-A Relation between median hearing loss and type of protection for ears (Internal vs. external): Right ear (Maico data).

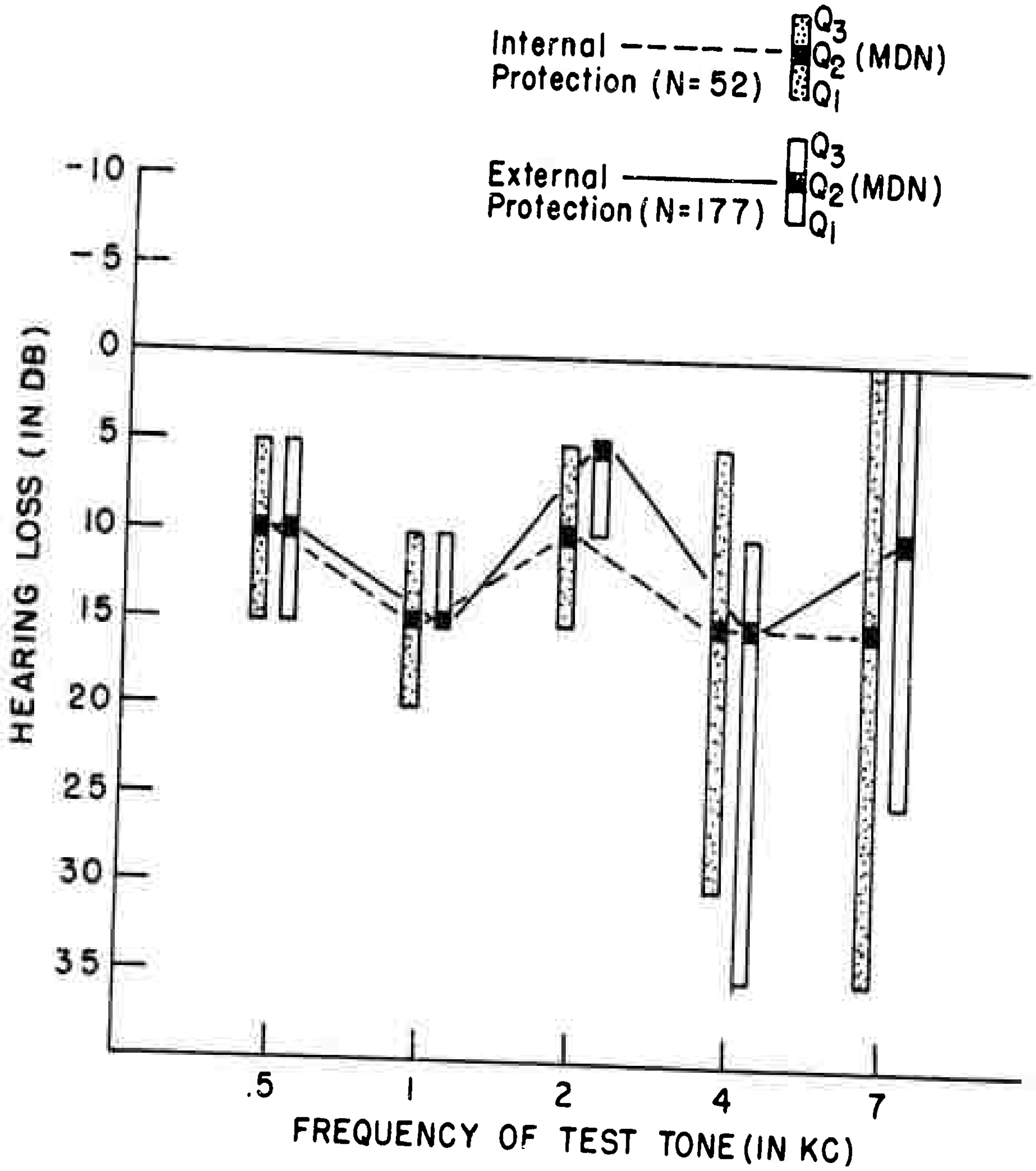


Fig. 16-B Relation between hearing loss and type of protection for ears (Internal vs. external): Left ear (Maico data).

A similar analysis was made on the NEL data. The results are shown in Figure 17. The paired-replicates test of significance could not be made on these data because of the small number of points, but no obvious trend is discernible in the data. As in the Maico data, there appear to be no hearing loss differences in the NEL Sample between those who wear internal ear protection and those who wear external ear protection. In considering these results it is appropriate to note that very few of the subjects had commercial ear plugs or knew how to use them properly. Dry cotton was the most frequently used internal protection; earphones (as used in a tank) the most frequently used external means of protection. Ear plugs were occasionally used, as were the hands.

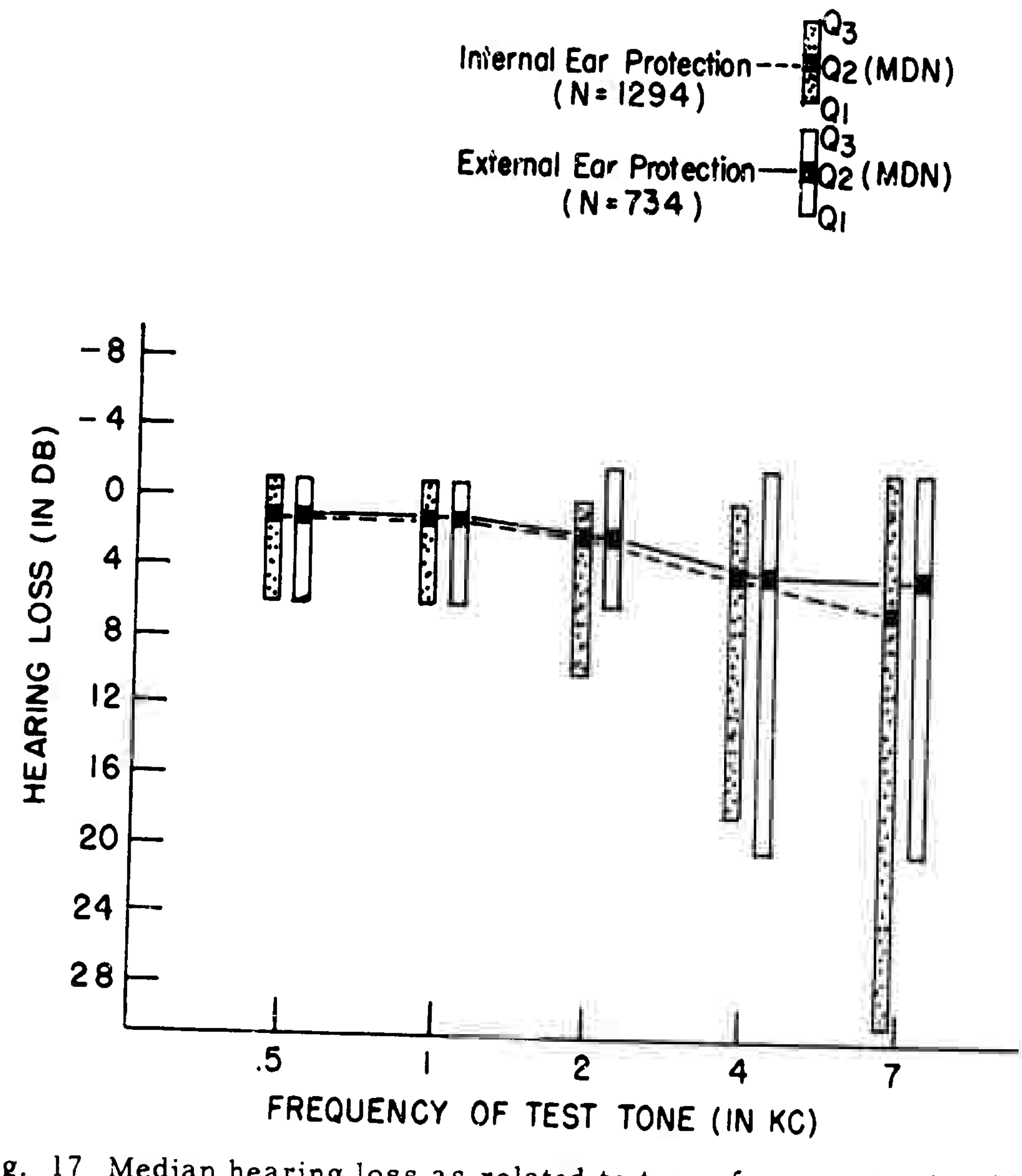


Fig. 17 Median hearing loss as related to type of ear protection (NEL data).

F. Hearing Loss as a Function of Branch of Service.

The hearing losses of subjects included in the NEL sample were tabulated and related to their branch of service (i.e., whether the subject was a tanker, an armor infantryman, or an armor artilleryman). The data from the NEL group are shown in Figure 18. No significant hearing loss differences among the Armor, Infantry, or Artillery subjects were revealed. This indicates that the median noise level and/or exposure time of armored infantry jobs, for example, probably does not differ markedly from the median noise level of Armor or armored artillery jobs.

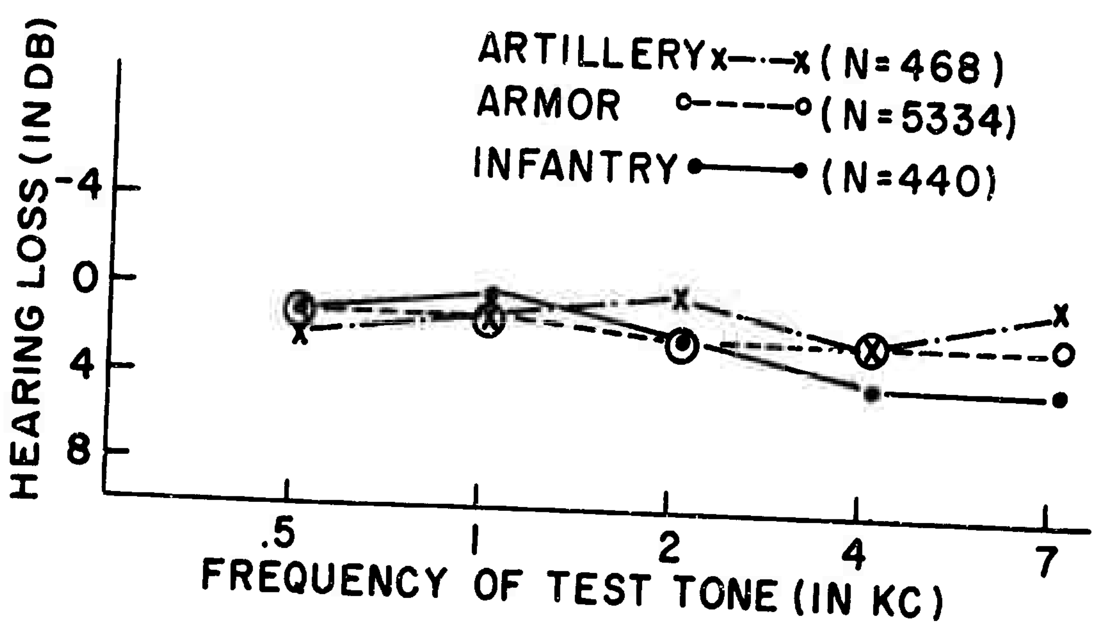


Fig. 18 Median hearing loss as related to branch of service (NEL data).

G. Type of Hearing Loss as a Function of Noise Exposure

The Maico data were analyzed to see if there were different type hearing losses for the different noise exposures, i.e., if those subjects exposed to a severe noise level had a larger number of perceptive type losses than did negligibly exposed subjects. The classification procedure for determining the type of hearing loss followed that used by Webster (7). Losses were called "normal" if the subject had a 5 db or less loss at 500 cps, and a loss not exceeding 14 db more than his loss for 500 cps at 8000 cps. The loss was called a "perceptive" loss if the subject had less than 5 db loss at 500 cps and more than 20 db loss at 8000 cps. Hearing loss was classed as "conductive" loss if the loss exceeded 5 db at 500 cps and was no greater at 8000 cps than 14 db more than that found at 500 cps. (In other words,

if the loss at 500 cps were 20 db, then the loss at 8000 cps could be as little as 0 loss and as great as 34 db and still be classified "conductive".) Loss was classed as combined perceptive-conductive if the loss exceeded 5 db at 500 cps and the 8000 cps loss was more than 15 db greater than the loss at 500 cps. The writers realize that diagnostic classifications can not be made adequately on the basis of air conduction test alone. The above classifications are merely taken as being indicative of what more precise diagnostic tests might possibly reveal.

Results of this analysis are presented in Figure 19. As might be expected, there were more "normals" among the negligibly exposed personnel than among the moderately or severely exposed. Perceptive

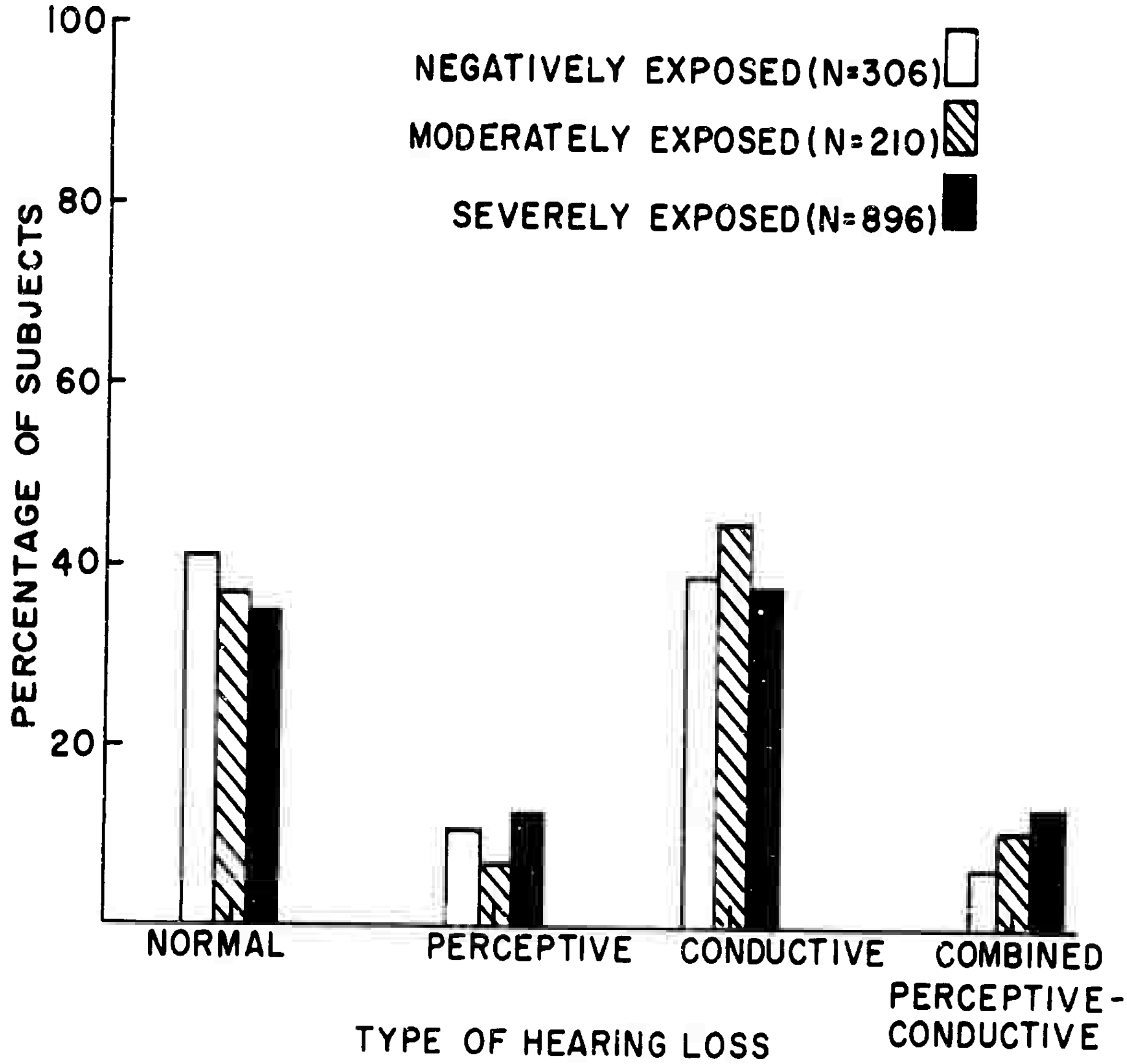


Fig. 19 Relation between type of loss and previous noise exposure.

loss for the severely exposed was somewhat higher than for the negligibly exposed. This result is in agreement with what would be predicted. The differences among the noise exposure groups with regard to conductive loss are inconclusive. The trend for combined perceptive-conductive loss was for such losses to increase from negligibly to severely exposed persons.

## IV. DISCUSSION AND CONCLUSIONS

The hearing of 3827 armor, armor artillery, and armor infantry personnel was tested. A hearing data questionnaire was completed for each subject. On the basis of the hearing data questionnaire, the subjects' hearing losses were related to age, noise exposure, use of ear protection used (internal or external), branch of service (armor, infantry, or artillery), and type of hearing loss as a function of noise exposure. Two methods of testing the hearing of the subjects were used, individual testing with a standard audiometer, and group testing with the NEL Recorded Warble Tone Test. The results of the two types of testing were compared and, with one exception, found to be quite similar. It was found that the right and left ears differed significantly (statistically) in their hearing loss scores when tested by an audiometer. No significant difference between ears was observed with the NEL group test data.

Generally, hearing losses increased with age, particularly hearing losses at the high frequencies. Median hearing loss differences were small but statistically significant between the negligibly and severely exposed individuals and were significant and somewhat larger in the 30-39 and 40-49 age groups. It was found that severely exposed personnel who wore ear protection against noise had statistically significant higher hearing losses than subjects in the same exposure category who did not use ear protection. Some possible explanations for this seeming paradox were offered. Hearing losses were shown to be greater for those with a "positive" medical history as compared with those who had a "negative" medical history. Subjects who had experienced tinnitus in a quiet place before being exposed to loud noises or gunfire, and subjects whose tinnitus persisted for longer than an hour after exposure to loud noises or gunfire, were shown to have significantly greater hearing losses than subjects who did not report these phenomena. No marked hearing loss differences were found between those subjects who used internally worn ear protection against noise and those who wore external ear protection. No consistent hearing loss differences were found among tankers, armor infantrymen, and armor artillerymen. Results of the analysis of the type of hearing loss as a function of noise

exposure were essentially inconclusive. There were more "normals" in the negligible exposure group than in the moderate or severe exposure groups. "Perceptive" loss tended to be higher in the severe exposure group. Combined "perceptive-conductive" losses increased with noise exposure.

Table 5 presents the Fort Knox (FK), the San Diego Fair (SDF), and World's Fair (WF) hearing loss data for the different age groups and for the 5 test tone frequencies used. The differences of the FK hearing loss data from the SDF and WF data were tested by the paired-replicates test and were found not be be significant.

TABLE 5

HEARING LOSSES FOR SAN DIECO FAIR (SDF), WORLD'S FAIR (WF), AND FORT KNOX (FK)+DATA FOR FOUR AGE GROUPS AND FIVE TEST TONE FREQUENCIES

| Age | Test Group | Frequency of Test Tone 440 | 880 | 1760 | 3520 | 7040 |
|---|---|---|---|---|---|---|
| 20-29 | SDF | -1.3 | -0.7 | 0.4 | 3.8 | 3.9 |
| | WF | 0.0 | -0.2 | -0.1 | 2.0 | 1.5 |
| | FK | 1.0* | 0.0 | 0.0* | 2.0* | 2.0* |
| 30-39 | SDF | 0.3 | 1.3 | 2.2 | 7.7 | 6.5 |
| | WF | 1.4 | 1.3 | 2.3 | 8.2 | 7.7 |
| | FK | 1.0* | 1.0* | 2.0* | 10.0* | 6.0* |
| 40-49 | SDF | 1.3 | 2.4 | 6.0 | 13.2 | 13.3 |
| | WF | 3.7 | 4.5 | 7.0 | 17.7 | 16.8 |
| | FK | 1.0* | 2.0* | 4.0* | 16.0* | 14.0* |
| 50-59 | SDF | 4.2 | 4.9 | 11.9 | 25.0 | 27.9 |
| | WF | 6.8 | 7.7 | 12.1 | 25.6 | 24.0 |
| | FK** | 6.0* | 7.0* | 16.0* | 44.0* | 34.0* |

+The values for the FK data are taken from Fig. 7.
*Frequencies for the FK data were 500, 1000, 2000, 4000, and 7000 cps.
**The FK data (N=22) included one subject 63 years old, no one else was older than 59.

Results of this study indicate that a group hearing test (specifically, the NEL Warble Tone Test) compares favorably with individual testing for use as a screening test and for large scale research on gross hearing loss where diagnosis is not necessary. The group test is preferable where large numbers of subjects must be screened. The smaller interval of the NEL test (1, 2, or 3 db, depending upon the intensity and frequency of the tone) as compared with the 5 db interval of the Maico H-1 audiometer, permits differences to be shown that might possibly be masked by the larger interval. An additional feature of the NEL test is that, because the instructions are recorded as well as the test, all subjects get exactly the same instructions and the testing procedure is more consistent. A comparative disadvantage is that nearly 30 minutes are

required for the subjects to complete the test, and their attention is likely to wander. The range of the NEL test (about 48 db, depending upon the biological baseline determination and the frequency of the test tone) constitutes one of its major weaknesses as compared with a standard audiometer. Frequently, loss at 4000 cps or higher can reasonably be expected to exceed 50 db in many people. In such cases hearing loss scores at the lower limit are an artifact of the restricted range of the test and could be confusing.

Some of the subjects tested in this study had been in service for as little as six months and had not been exposed to severe noise levels for any appreciable length of time, yet had severe hearing losses. This indicates that they could have had such losses when they entered service. When questioned, they indicated that no adequate test had been made of their audiotory acuity upon entry into service. In view of the cost of service-incurred hearing loss to the government, it would seem that all incoming personnel should have, as part of their physical record, an audiometric examination.

One possible interpretation from this survey is that older persons suffer proportionally greater hearing losses upon exposure to a given noise level than do younger persons. Consistent with this interpretation, it would seem prudent to exercise particular caution in assigning those over 30 years old to loud noise jobs.

Subjects who experienced tinnitus prior to loud noise exposure and subjects whose tinnitus persisted for longer than an hour after loud noise exposure were found to have greater hearing losses than those who did not experience these phenomena. Further research is indicated to determine whether experiencing these phenomena is indicative of susceptibility to noise induced hearing losses.

In view of the comparability of the group testing procedure results with those obtained by individual testing, it appears that, in situations requiring that large numbers of persons be screened for gross hearing losses, group testing methods might profitably be utilized. The subjects test results could be quickly obtained and those who appear to have significant losses could be given further, more intensive individual testing.

In summary, hearing losses, particularly at high frequencies, were found to increase with age. The results of individual and group audiometry were found in essential agreement. Hearing losses were greater for severely than for negligibly exposed subjects, with the differences

in median hearing losses between negligibly and severely exposed personnel greater for persons over 30 years of age. Hearing losses were larger for personnel who had a "positive" aural medical history. Tinnitus prior to loud noise exposure and persisting tinnitus after exposure could be indicative of susceptibility to noise induced hearing loss. There appeared to be no significant difference in hearing loss scores as a function of wearing internal ear protection as compared with external protection. No significant difference was found in the hearing loss scores for armor, armor infantry, and armor artillery personnel. The analysis of type of hearing loss as a function of noise was inconclusive.

## VI. RECOMMENDATIONS

An audiometric examination under adequate testing conditions should be made of all incoming military personnel.

Caution should be observed in assigning persons 30 years old or older to high noise level jobs.

Further research is required to determine whether tinnitus prior to loud noise exposure and tinnitus which persists for longer than an hour after loud noise exposure indicates susceptibility to noise induced hearing loss or only indicates that a loss has already occurred.

A hearing conservation program should be instituted as soon as possible and actively enforced for all armed forces personnel.

## VII. BIBLIOGRAPHY


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# APPENDIX I

Age - the subject was requested to put down his age, in years, as of the date of testing.

Total Active Service - it was asked that the total amount of active military service, in months, be entered here.

Name - subjects were required to print their name in this blank.

SN - the army serial number was required to be written in this space.

Unit - the information desired here was, "What is your branch of service (infantry, artillery, armor)?"

Current Noise Exposure: Job - the question asked in this section was, "What is your current job assignment (driver, rifleman, etc.); if driver, state type of vehicle; if instructor, type of instruction."

Length of Time - here the subject was asked to write how long he had held his current job.

Protection - the subject was asked to indicate here whether or not he wore ear protection against noise (to include earphones in a tank); if so, to say how frequently such protection was worn.

Type of Protection - the subjects who indicated they had used ear protection against noise were requested to circle the type of protection they had used. If the type they used was not specifically listed, they were to make choice 6, Other, and write out the type they had used. It was explained to all subjects that number 5, Helmet, meant the tankers helmet, not the ordinary steel helmet.

Previous Noise Exposure: Military - this section required the subject to indicate all jobs (other than his present one accounted for above) he had held in service and how long he had held each one.

Combat Exposure - the subject was told to say whether he had ever been in combat and exposed to heavy and/or light arms fire; if so, for how long he was actually under fire. The last part of this section asked if the subject had had basic training; if so, what type (infantry, artillery, medical, etc.). If he had had more than one basic course, he was asked to list them all.

Evaluation of Noise Exposure - the evaluation of the military noise exposure was made by the experimenters on the basis of the subject's military noise exposure data and was rated either negligible, moderate, or severe.

Civilian Jobs - the information required here was whether the subject had ever had any civilian jobs where he worked in a noisy place (defined to the subject as any place where he could not converse with fellow workers in a normal tone of voice where they were within a few feet of him). If he had held a noisy job or jobs, he was asked to indicate how long he had worked at each job.

Medical History - the subjects were told to be sure to answer every question in this section either yes or no. If possible, where the answer to a question was yes, the subjects were asked to say whether the left or right ear, or both ears, was affected.

Aural Pain - the question asked here was, "Have you ever had earaches, not a single earache, but earaches; if so, in which ear?"

Drainage - the information requested here was whether the subject's ear or ears had ever drained or run or had a bloody or pus discharge.

Ear Injury Mech. - this section wanted to know if the subject had ever sustained any mechanical injury to his ears, such as a blow or perhaps being punched in the ear by a sharp object.

Surgery (Ear or Mastoid) - the subjects were asked to mark whether they had ever had their ear or ears lanced, or any operation on the ear, or a mastoid operation.

Tinnitus Prior to First Exp. - the question asked here was, "Have you ever heard or been bothered by a ringing or buzzing sound in your ears when you are in a quiet place and before you have been exposed to loud noises or gunfire?" This section and the one immediately following usually required further elaboration and/or explanation.

Tinnitus Following First Exp. - this section wanted to know whether the subjects ears ring or buzz for longer than an hour after he has been exposed to loud noise or gunfire.

Remarks - subjects were told to put in the Remakrs section anything that had ever happened to them that they felt might help the experimenters evaluate their hearing. As an example, they were told to include instances

where guns or shells had gone off near them and temporarily deafened them or made their ears ring for prolonged periods of time.

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